TECH ENGINEERING NEWS

FEBRUARY · 1939

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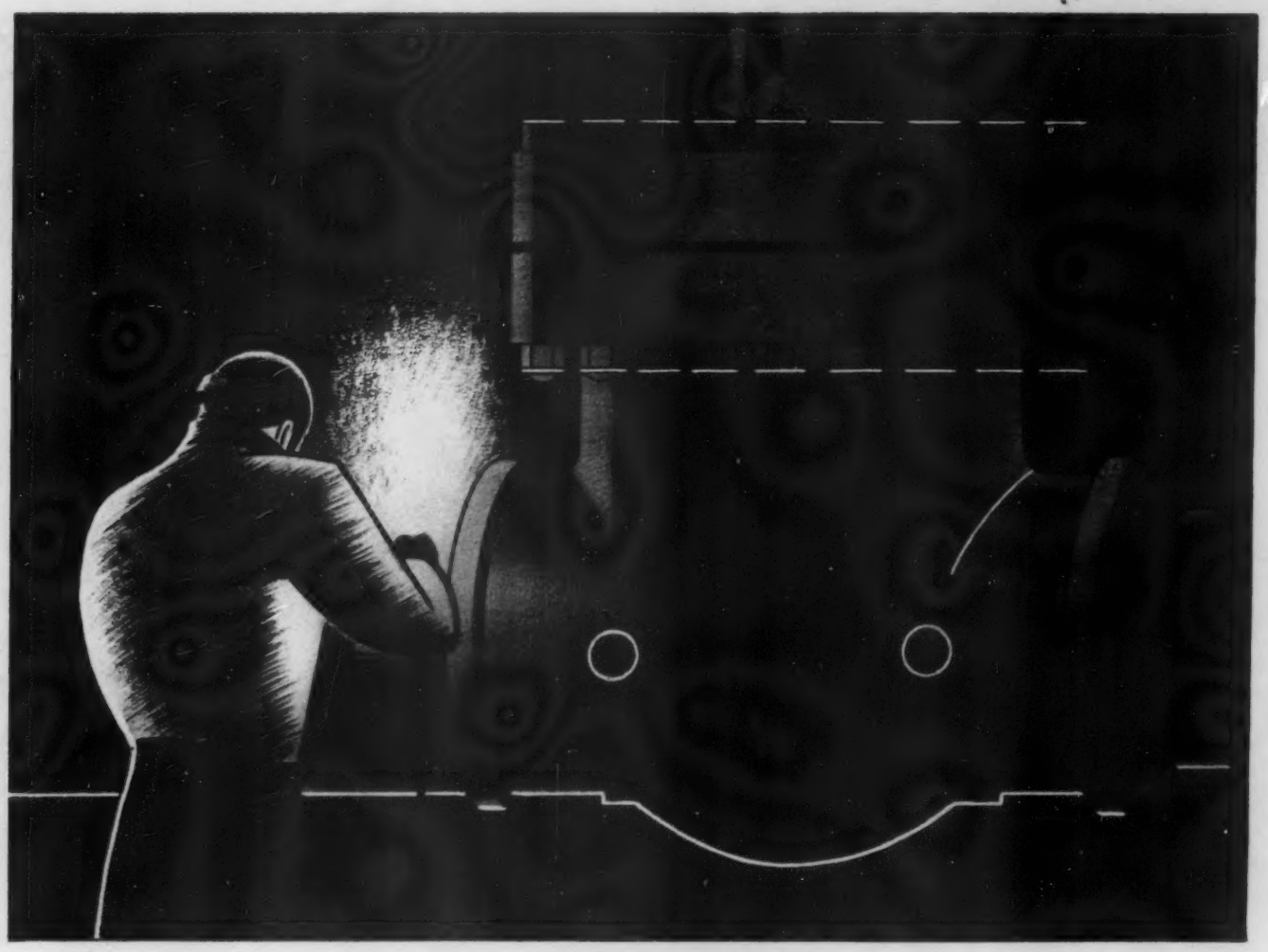

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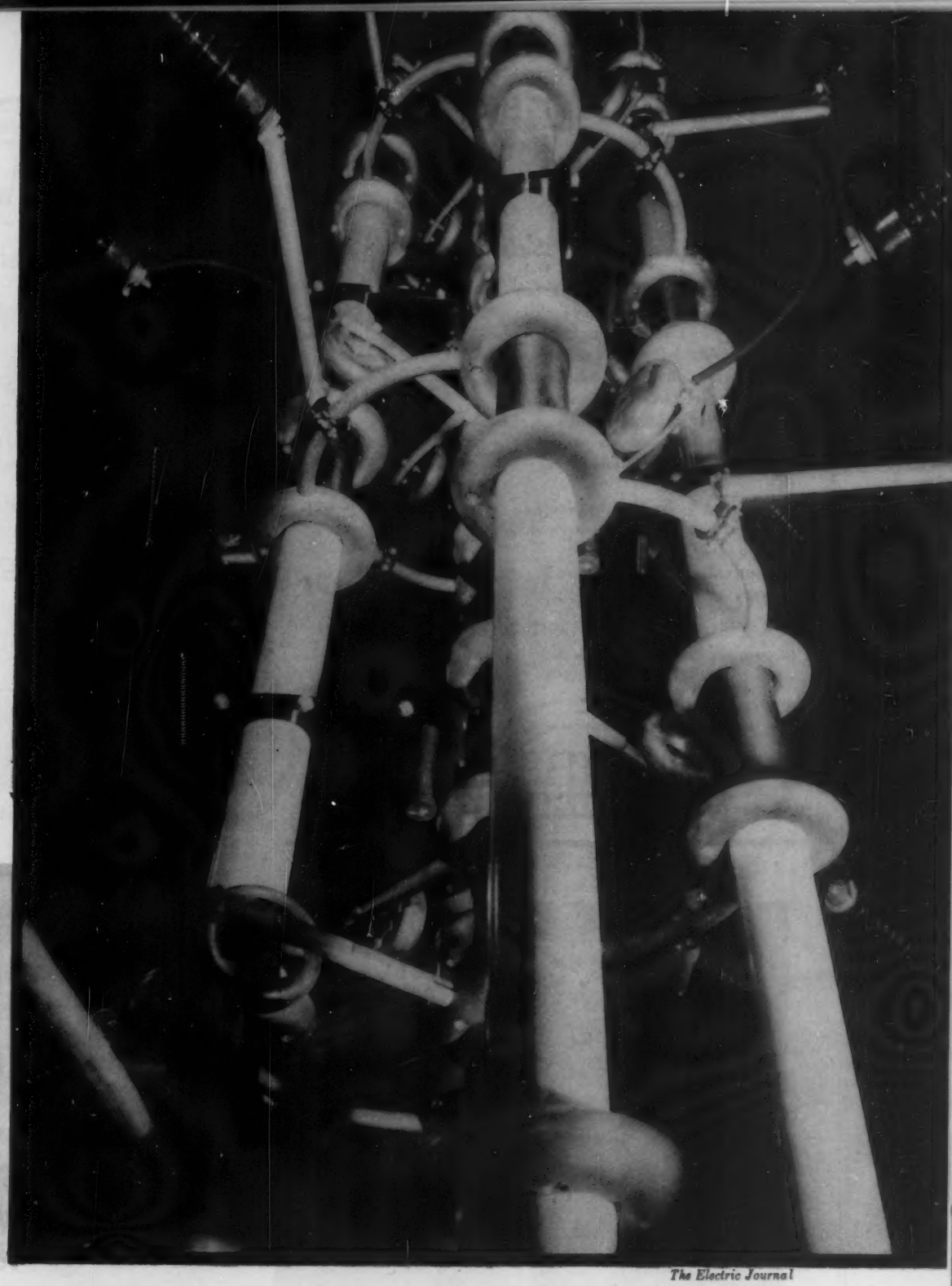

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The Electric Journal

OUR AUTHORS

JOSEPH D. EISLER, '32, contributes this month's article on petroleum prospecting. Mr. Eisler was graduated in the Honors group of the Electrical Engineering Department at the Institute. He is now employed as seismologist in the Geophysical Department of the Stanolind Gas and Oil Company at Tulsa, Oklahoma. Mr. Eisler is an associate member of Sigma Xi and an active member of the Society of Exploration Geophysicists.

MALCOLM F. JUDKINS is the chief engineer of the Firth-Stirling Steel Company, and although only thirty-three years of age he is a member of the United States Bureau of Mines Research Fellow Metallurgical Advisory Board. Mr. Judkins received his Bachelor of Science Degree in Chemical Engineering from the University of Washington and his Master of Science Degree in the same field from the Carnegie Institute of Technology. Besides holding the position of treasurer of the Pittsburgh Chapter of the A. S. T. E., he is chairman of the A. S. M. E. Special Research Committee on Cutting of Metals. This varied career of technical experience has made Mr. Judkins especially qualified to write the article in this issue of the TECH ENGINEERING NEWS entitled "Sintered Carbide Tipped Tools."

AMOS J. SHALER, '40, interested in solar-terrestrial relationships since his freshman year at the Institute, took a leave of absence after his sophomore year, to give more time to the study. The preliminary results of his work in collaboration with Richard Novak, '39 are now being published. Mr. Shaler has been appointed secretary of an International Congress in Astrophysics to be held in Paris next summer.

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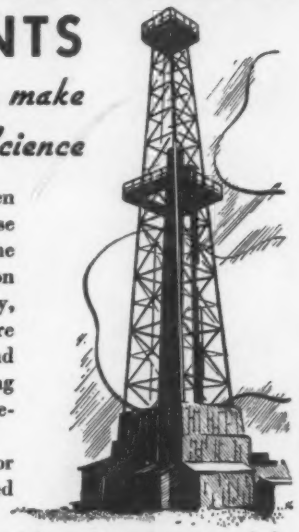

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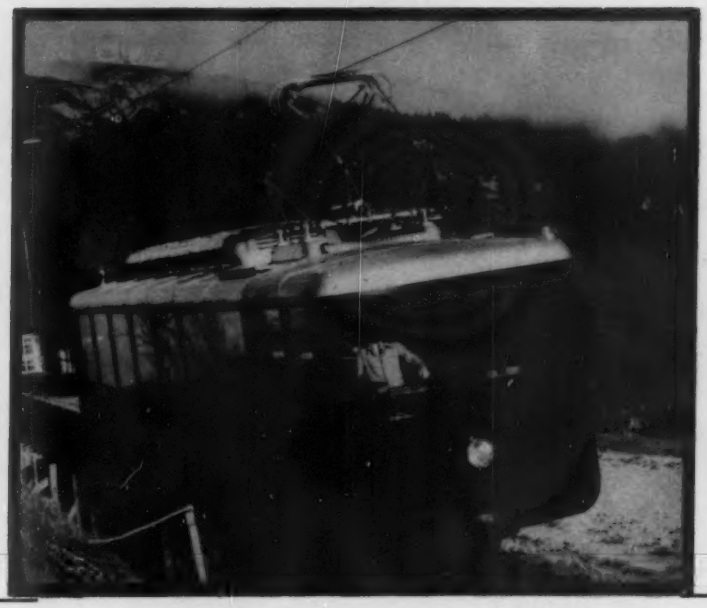

VOLUME XX NUMBER 1

E. I. duPont de Nemours

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OUR COVER THIS MONTH

A phase in the manufacturing process of Jenkins Valves.

Published monthly throughout the school year, at Walker Memorial, Cambridge A, Massachusetts, by the undergraduates of the Massachusetts Institute of Technology. Entered as second class matter, at the Post Office, June 1, 1920 at Boston, Mass., under the Act of March 3, 1879. Copyright 1939 by The Tech Engineering News.

Subscription per year $1.50. Foreign $1.75. Single copies 25 cents.

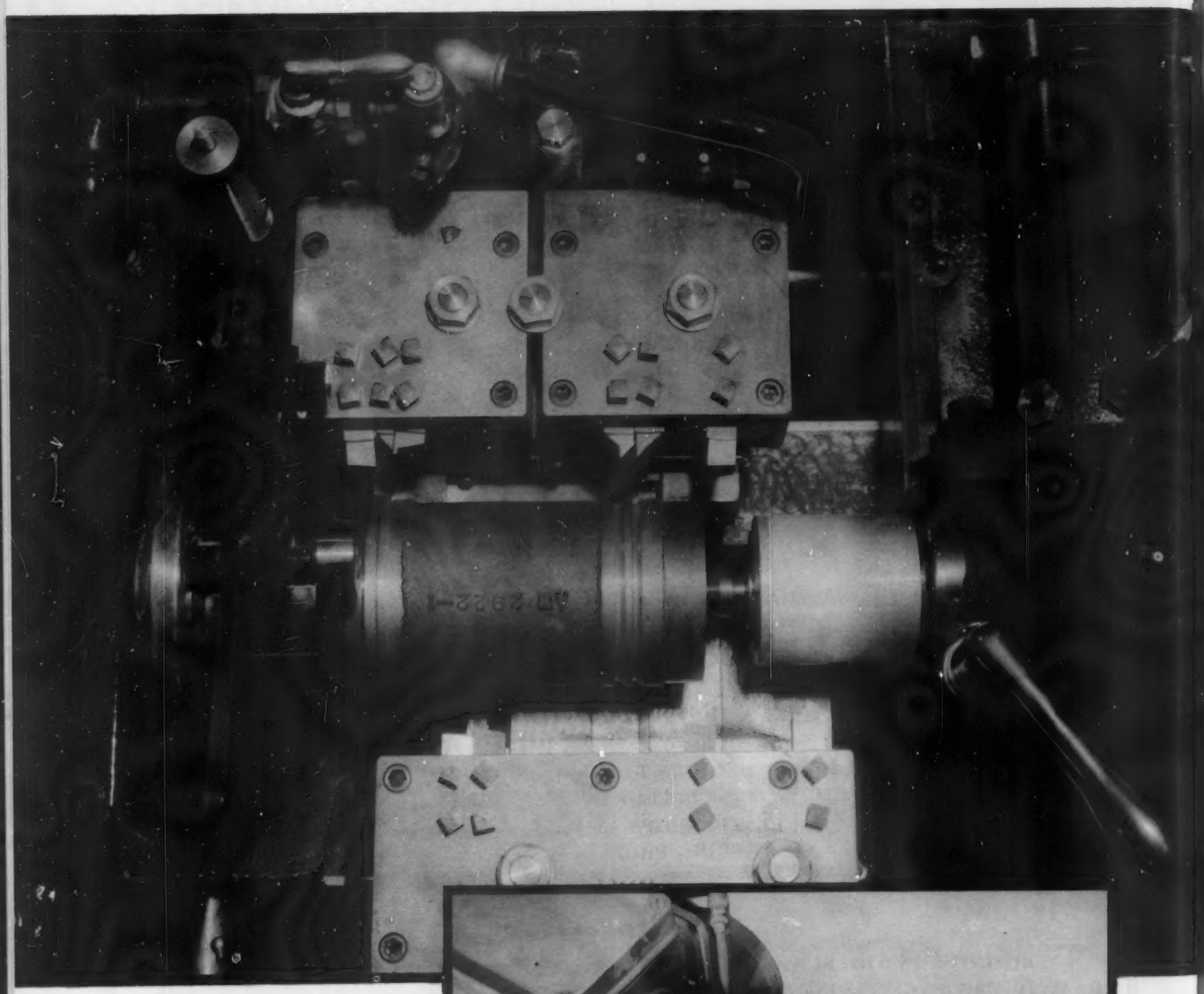

Figure 9

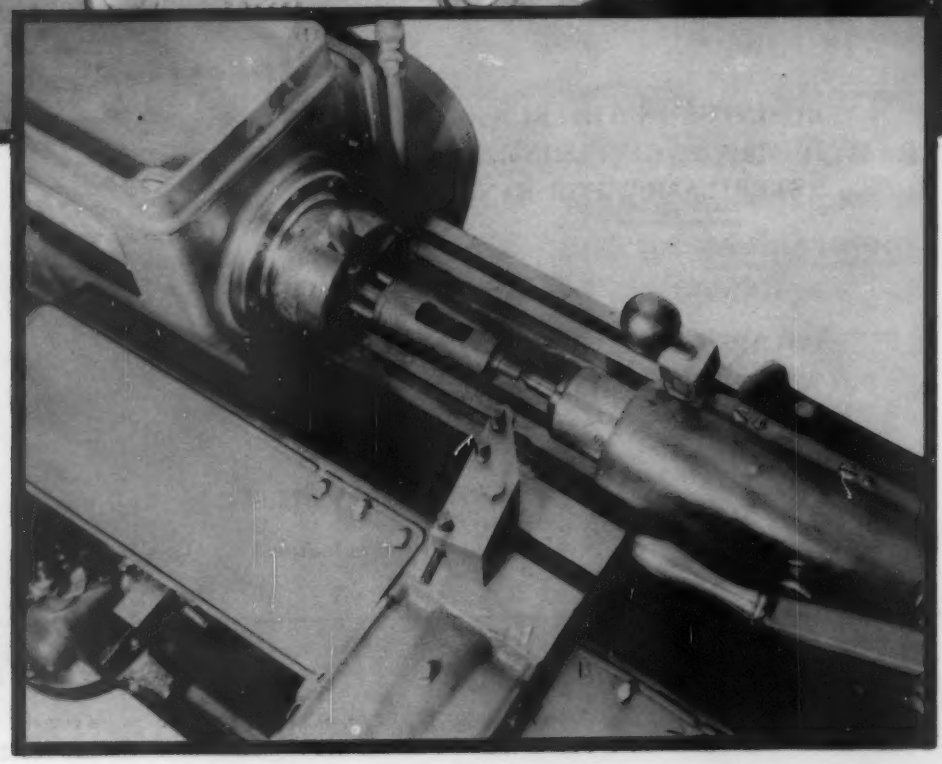

Figure 7

Figure 1. Microstructure of sintered cobalt carbide with six per cent added

Figure 2

Milled tip recess in tool shank *Carbide tip fitted to shank recess* *Brazed only tool*

Sintered Carbide Tipped Tools

● KEEN EDGED CUTTING TOOLS FROM SINTERED TUNGSTEN CARBIDE — A MATERIAL ENDOWED WITH SUPERLATIVE RESISTANCE TO ABRASIVE WEAR AND A COMPRESSIVE STRENGTH EXCEEDING THAT OF ANY KNOWN MATERIAL

MALCOLM F. JUDKINS
Chief Engineer, Firthite Division, Firth-Sterling Steel Company, McKeesport, Pa.

IN the preceding installment* the historical development and method of manufacture of sintered tungsten carbide were briefly reviewed. The unique advantages of the sintering method over the conventional metallurgical processes of melting, casting, forging, and rolling were noted and discussed. The implications and probable future application of the powder metallurgy technique to other products than hard metals for cutting and wear-resistant purposes were considered.

In this concluding chapter we shall briefly study the physical and chemical characteristics of sintered carbides, the design and fabrication of tipped tools and their application to the cutting of metals and abrasives as well as to the wear proofing of parts subjected to abrasion.

Tungsten forms two carbides corresponding to the chemical formulae W_2C and WC. Melting points are 3000 and 2900°C. respectively. Densities are 16.9 and 15.5 respectively. The subcarbide, containing approximately 3.16 per cent of carbon, forms on saturating a melt of tungsten with graphite. The monocarbide, WC, containing 6.12 per cent carbon, decomposes on melting, rejecting graphite and W_2C. In the manufacture of sintered tungsten carbide it will be recalled that the monocarbide is produced by carburizing pure tungsten powder which has been thoroughly mixed with the calculated proportion of lampblack. The carburizing must be effected in a pure, dry, hydrogen atmosphere in the presence of excess carbon in the form of a graphite carburizing tube. No partial pressure of oxygen or water vapor is permissible. Rigid atmosphere control is necessary to prevent oxidation, decarburization, or surface composition variations which might induce diffusion resulting in heterogeneity of structure and properties.

W_2C crystallizes with a hexagonal close packed lattice, while WC is found to possess a hexagonal lattice of crystal structure. X-ray diffraction measurements indicate lattice parameters of $a=2.94$ A°; $c=2.86$ A° for WC and $a=2.99$ A°; $c=4.72$ A° for W_2C. Calculations for both carbides disclose carbon atoms with atomic volumes identical with diamond. Becker's work on the W−C system implies that the unusual hardness of tungsten carbide may be due to this cause.

Sintering a comminuted compact of powdered tungsten carbide and cobalt at a temperature in the neighborhood of 2700° F. involves the formation of a WC−Co eutectic consisting of 27.5 per cent WC dissolved in 72.5 per cent Co. This phase liquefies at the sintering temperature. Because the solid solubility of WC in Co is considerably less than the liquid eutectic proportions, cooling to room temperature involves rejection of WC until the terminal solid solution composition is reached. The WC "plates out" on adjacent WC crystals, restoring their regular polygonal outlines which suffered erosion during the solution effect of the cobalt at the sintering level.

As previously noted, however, the "cement" which

* May 1938 TECH ENGINEERING NEWS.

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Muffles	- 400/500 hrs- 5.50pr.	- 350/450 hrs -$13.50pr.
Kw. consumption	- 1.75/hour	- 4.00
Braze up to	- 1-1/4"sq. tools max.	- 2-1/4"sq.tools max.
No.tools per hr.1/2"	- 40	- 4
Hydrogen consumption	- 5 cfper.hr.each muf.	- 15 cf.per hr.

TABLE II

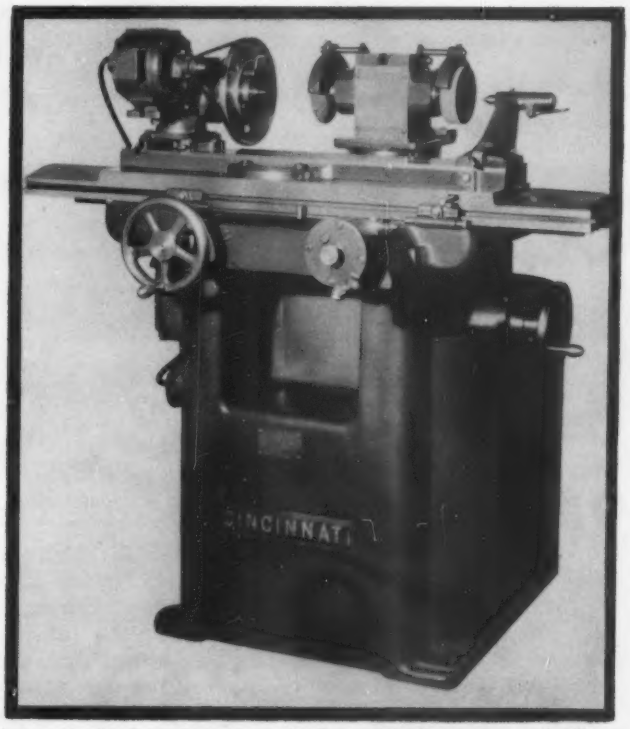


Figure 6. Tool and cutter grinder well adapted to grinding flat forming tools and resharpening face mills

At top, Figure 3. General view of the brazing room at the main works in McKeesport, Pa.

binds the WC crystals together is not Co but a Co-rich solid solution of WC. Figure 1 shows the microstructure of a polished and etched section of sintered carbide with 6 per cent added cobalt. The photomicrograph was taken at a lens magnification of 1500X. The crystals bordered in black are WC, and the lighter intervening areas are the "metallic cement"— the Co–WC solid solution. The longest dimension of the WC crystals is about 2μ or approximately eighty microinches.

In order to provide materials uniquely adapted to perform most efficiently and economically under the widely differing service conditions required by the modern manufacturing scheme, a variety of grades of sintered carbides is produced. The required range of physical properties is realized by varying the proportion and type of binder (present grades contain from 3 to 25 per cent of added cobalt), by variations of particle size, grinding or milling practice, compacting pressure and time, temperature, and method of sintering. To the basic tungsten carbide varying proportions of tantalum and titanium carbides are added to provide grades for special purposes. Certain compositions possess remarkable resistance to corrosion, chemical attack, and to oxidation and other forms of deterioration and change at elevated temperatures.

Quality Control Tests

The manufacture of sintered carbides is on a batch-process basis. Uniformity necessary to consistent performance requires careful quality control tests. Pilots or test plugs must meet quality test requirements before the batch of powder represented is released for pressing and sintering.

As a joint result of the unique physical character and cost of the hard sintered carbides, the usual form of cutting tool is composite. The carbide tip, designed to do the cutting, is joined to a supporting steel shank. Occasionally, however, small bits of solid carbide are used as tools. Tool tips are customarily attached to supporting shanks by brazing, soldering, or mechanical methods such as clamping.

The most publicized property of sintered carbides is their superlative hardness and consequent remarkable resistance to abrasive wear. A more important property in its effect on tool design is the tremendous compres-

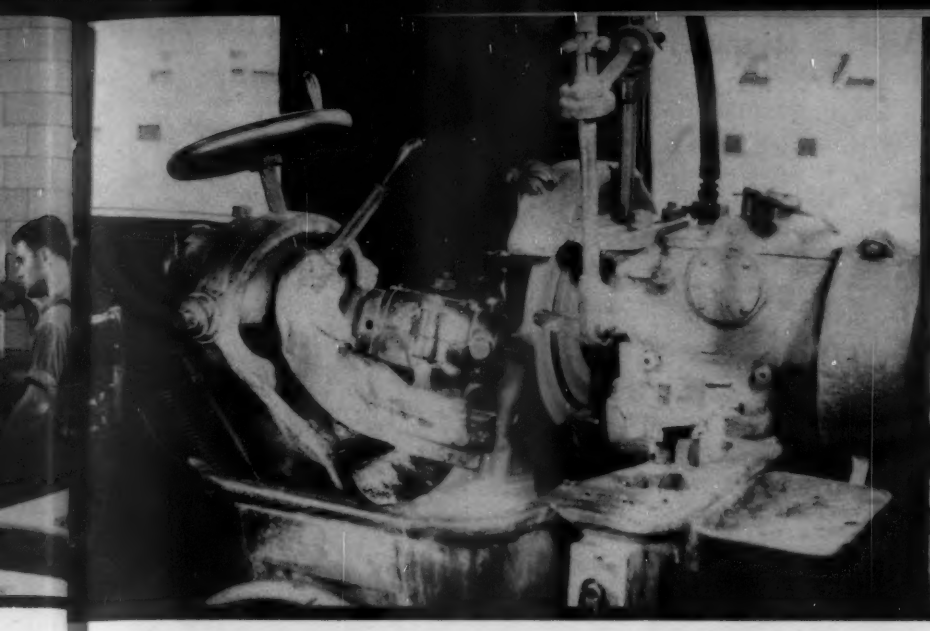


Figure 4. Rapid removal of stock without damage to the carbide tip characterizes this machine

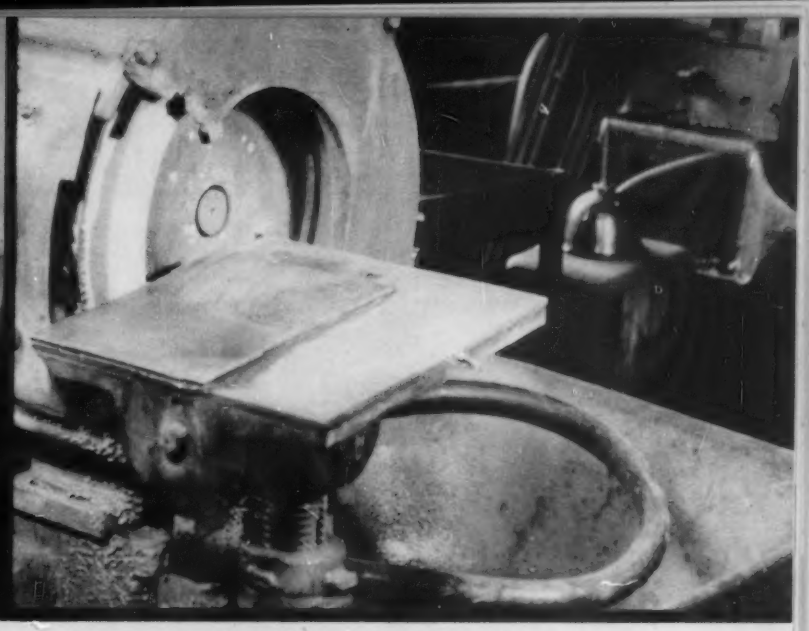


Figure 5. Machine for semifinish angle grinding

sive strength of sintered carbides which exceeds that of any known material. Immediately, the use of a deep, rigid tool shank is indicated. A single point lathe tool is a cantilever with the overhang of the cutting point beyond the tool block or holder corresponding to the unsupported beam length. If deflection under the loads imposed by cutting can be prevented or minimized by placing sufficient metal beneath the carbide tool tip the rather low tensile strength and low bending moment of sintered carbides need cause no concern — they cannot be crushed or broken if properly supported.

The kind of shank steel must be decided from an examination of service requirements. Even for light work such as precision boring, the shank steel must meet certain exacting specifications. It must be readily wet by the brazing material and capable of forming a sound brazed joint with the carbide tip. The steel must acquire through the heating and cooling incident to the brazing process a suitable hardness to resist moderate abrasive wear and objectionable set screw indentation, and yet it must not have thermal expansion characteristics which impose strains upon the brazed joint or cause stresses within the carbide tip serious enough to cause warpage or rupture.

The selection of cutting edge contour is usually a compromise. A large nose radius, or an acute angle of presentation of a straight cutting edge relative to the work axis, will usually increase durability or tool life since wear will be most rapid and severe where the cutting edge contour changes direction abruptly, and because both curved and angularly presented straight cutting edges decrease the chip thickness and increase the lateral spread of the chip, reducing cutting pressure per unit length of cutting edge. Both, however, increase the total cutting edge engagement with the work, as well as the total cutting force, and either may cause "chatter" which is destructive not only of a satisfactory machined finish but of the tool's cutting edge itself in severe cases.

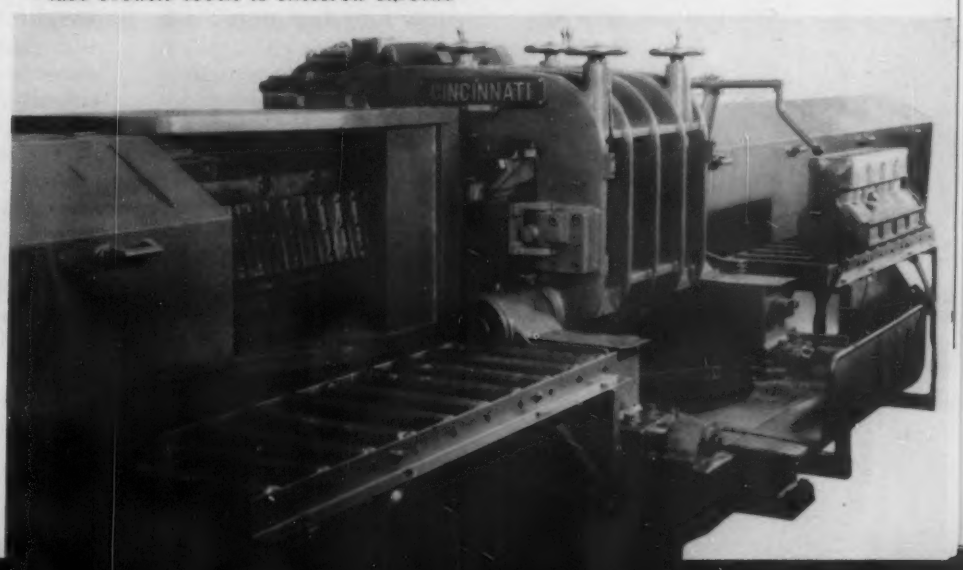
Paramount among tool design factors is grade selection. To achieve maximum efficiency and economy, a cutting tool material must be manufactured in a variety of types or grades individually adapted to a unique class of machining operation on a limited group of materials. The highly competitive nature of the cutting tool market has forced research and development of tool materials to discover the one best grade and method.

If the ultimate in rapidity and economy of production of machined work is not essential, considerable latitude in grade selection is possible. Merely naming the material to be cut and indicating the type of machine tool and the nature of the cutting operations to be performed will permit choosing an effective grade for the purpose.

If, on the contrary, the production schedule demands minimum cost and a minimum of interruption for tool changes, each application must be critically examined before the most applicable grade of sintered carbide can be determined. The bases of grade selection for a particular cutting problem include: the operation; the machine tool; the material to be cut; the part to be machined; the present or proposed machining practice; and the characteristics of the cutting tool material to be used. In general, milling, planing, and turning of parts with interrupted cuts all require a tough, shock resistant grade of sintered carbide. Still greater impact resistance and rigidity are required for blanking and punching. At the other extreme, precision boring with shallow cuts, fine feeds, and high speeds, as well as sawing of hard, abrasive, or gritty materials, may require the ultimate in hardness and resistance to abrasive wear, with strength or brittleness of relatively small moment. Necessary resistance to oxidation at elevated temperatures or chemical attack by corrosive solutions or gases may demand a grade of high degree of chemical inertness. If the material to be cut is metallic, its history of manufacture, chemical composition, and present physical condition are all of vital importance to grade selection. Both forgings and castings are likely to have a hard and abrasive scale or skin, but inherent structural

(*Please turn to page 18*)

Figure 8. Mass production surface broaching of automotive engine castings — last broach tooth is sintered carbide



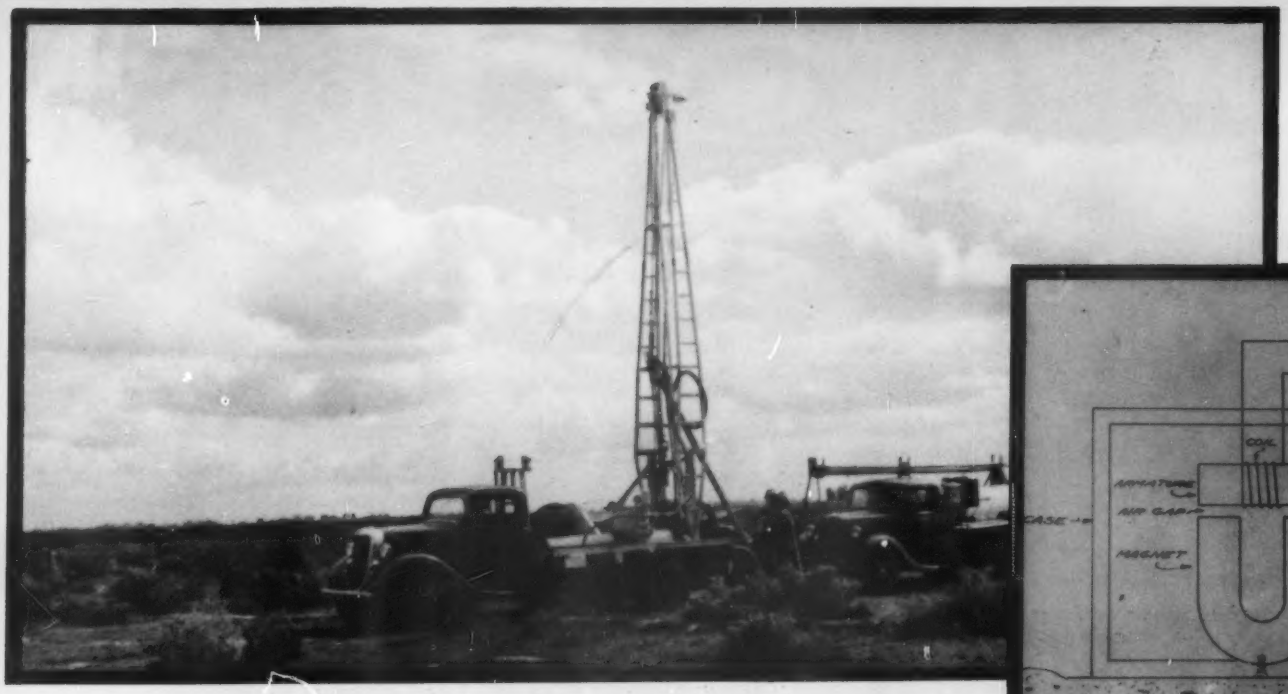
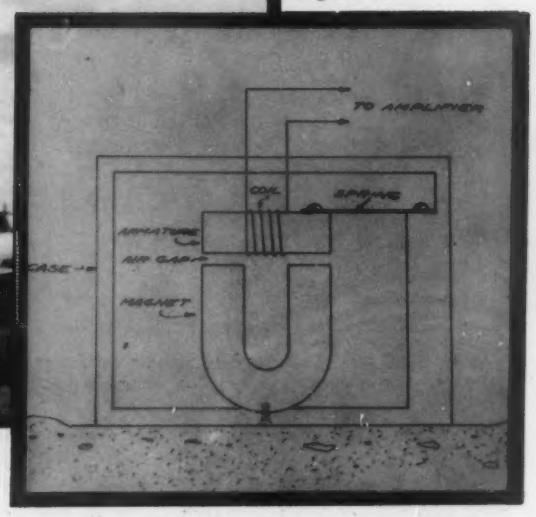


Figure 1



Searching for Oil

● BY DRILLING, DYNAMITING, AND SCIENTIFIC RECORDING. RECORDING THE SOUND REFLECTIONS OF THE INVISIBLE STRATA WHICH MAY SHELTER OUR VAST RESERVES OF BLACK GOLD

JOSEPH D. EISLER

GEOPHYSICS means physics of the earth. Applied geophysics has to do with those phases of the science which deal directly or indirectly with problems ensuing from man's search for minerals, oil, and other natural wealth which is found beneath the surface of the earth. At the present time oil is by far one of the most important items from an economic standpoint. Due to a great consumption of oil by industry and by the public as motor fuel there is a perpetual trend among the oil companies not only towards increasing their production, but their oil reserves as well.

The total estimated reserves of crude oil in this country prior to September 1, 1938, amounted to 13,584 million barrels, of which 10,300 million barrels have been drawn already, leaving over 3,200 million of crude oil reserves to be drilled in the future. From available figures the estimated amount of oil required for the next 20 years is 28 billion barrels. Up to 1938 the average discovery rate of potential oil fields amounted to one billion barrels per year, and if the discovery rate does not drop off, the expected need may be satisfied. From the foregoing it is evident, therefore, that applied geophysics face a practically unlimited field of action, eventually to be curtailed, perhaps, either by a discovery of a satisfactory substitute for oil or prohibitive cost of prospecting.

There are a number of methods at the present time which enjoy greater or lesser popularity as a means for a successful search for oil. Some of them are employed purely as reconnoissance methods, due to the rapidity and cheapness of operation; others are employed for more detailed mapping of subsurface geological structures bearing oil and are perforce slower and more expensive of operation. Below is given a list of the present day methods, some of which are of long standing (discovered as far back as the middle of the last century), and some of which are of quite recent origin. Some of the methods are used by practically all of the companies engaged in the field, and some used by companies which specialize only in one or two methods.

A. Gravity methods
- (1) Torsion balance
- (2) Gravimeter

B. Magnetic methods
- (1) Magnetometer

C. Electrical methods
- (1) A.C. or D.C. steady state
- (2) Transient

D. Seismic methods
- (1) Refraction
- (2) Reflection

E. Miscellaneous
- (1) Well logging
- (2) Soil analysis
- (3) Radio methods

The torsion balance measures the horizontal gradient of gravity. One common form consists of a light weight beam suspended by a fine wire. A mass is attached to one extreme end of the strut and another mass is suspended by a wire from the other end. The masses and points of suspension are so chosen that the beam remains suspended horizontally. The differences in the pull of gravity at the two masses, which is indicatory of a subsurface anomaly in the distribution of density, has a horizontal component which causes the beam to rotate about the suspension. The amount of rotation is recorded either visually or photographically.

Exploration by means of gravimeters entails mapping of the changes of the pull of gravity over an area

* Geophysical Laboratory, Stanolind Oil and Gas Company, Tulsa, Okla.

which result from the presence of subsurface anomalies. The exploration is carried out by the use of an extremely delicate and sensitive arrangement of a mass suspended either by a torsion member or a spring. Modern instruments are sufficiently sensitive to detect a change in the pull of gravity due to change of elevation of one foot above the earth's surface. In terms of gravity this amounts to (approximately) 0.5×10^{-8} gr. The method, thanks to its rapidity and cheapness of operation, enjoys increasing popularity as a reconnaissance method.

A magnetometer is a sensitive arrangement of a magnet or magnets which is acted upon by the earth's magnetic field. A body of magnetic ore or other cause of a magnetic anomaly, such as a buried granite ridge, tends to distort this field, causing the magnetic member to deflect from its normal position. This method is not applicable for petroleum prospecting except in the case of rare types of structures, and its use is limited almost entirely in discoveries of magnetic ore bodies.

Electrical methods of prospecting by the use of steady state D.C. or A.C. measure the resistivity of the underlying rocks between two points on the earth's surface. The changes of resistivity are indicative of subsurface anomalies, such as faults. The transient methods measure the combined resistive and inductive effects of subsurface strata due to a loop of current induced in a vertical plane in the earth. All electrical methods consist of passing a current (either steady state or transient) into the earth at two points a finite distance apart and measuring the resultant potential at two other points in the vicinity.

Well-logging is closely related to the electrical methods of prospecting except that the resistivity is measured at points in a deep well which may be an abandoned bore hole, a dry well, or a producing oil well. The change of resistivity with depth is indicative of the change of rock material of the subsurface strata. If several wells are surveyed in the above manner in a given territory, the subsurface layers can be traced from one well to another and a more or less complete contour map of the region obtained.

Soil gas analysis is a method which consists in the sampling of absorbed or adsorbed gases in the soil and subsequently microanalyzing them for the heavy hydrocarbons, such as butane and propane. The presence of those gases in the soil atmosphere is said to be indicative of an accumulation of oil below the surface. The method is still in its infancy and difficulty is being experienced in providing sufficiently accurate and sensitive analysis (two parts per billion), and in the interpretation of the data.

Various radio methods, employing directional radio beams and measuring either the reflection of this beam or its absorption by various subsurface strata, are in an elementary stage of development. At the present time, radio methods are of small commercial significance.

The refraction method of prospecting was one of the most successful methods up until a few years ago, at which time it was superseded by the reflection method. This method was notably successful in the discovery of Gulf Coast salt domes of moderate depth. It measures the velocity of propagation through the earth of an elastic wave initiated by an explosive. In order to obtain the travel time for deep beds, great distances are required between the point of explosion and a vibration pickup, necessitating excessively large charges of explosive. While the method is still used in some foreign countries, it has been completely supplanted in this country by the reflection method.

The seismic reflection method is the most direct and powerful method for petroleum exploration at the present time. The first step is the initiation of a sound wave with a very sharp wave front (produced by a charge of dynamite set off in a shallow well drilled expressly for that purpose). The wave travels downward with a spherical wave front and as it encounters strata of varying composition and density (*i.e.*, subsurface discontinuities), part of it is refracted and part of it is reflected in a manner similar to the well-known laws of optics. The reflected wave travels upward and impinges upon sensitive vibration pickups called variously seismometers, geophones, or receptors (see Fig. 1), which are placed on the surface and usually in a straight line (see Fig. 2). The seismometers convert the mechanical energy of the reflected wave into electrical energy. The latter is suitably amplified and recorded on a multi-element oscillograph. Either one or a group of seismometers are connected to an individual amplifier channel whose output is connected to a single trace of the oscillograph. At the present time there is a tendency to use 30 or more seismometers and between 10 and 15 individual amplifier channels and oscillograph traces.

Provision is made to record the instant of the explosion of the dynamite charge (see Fig. 3). This is done by recording on one of the oscillograph traces the instant

(*Please turn to page 22*)

Figure 2

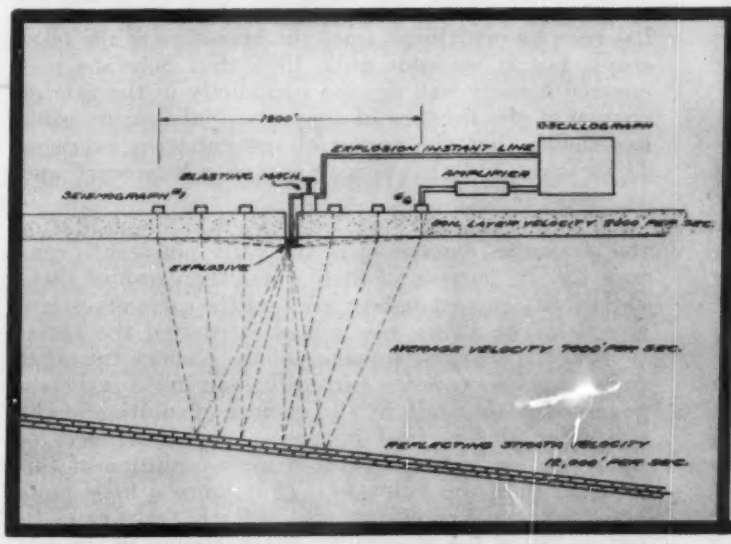
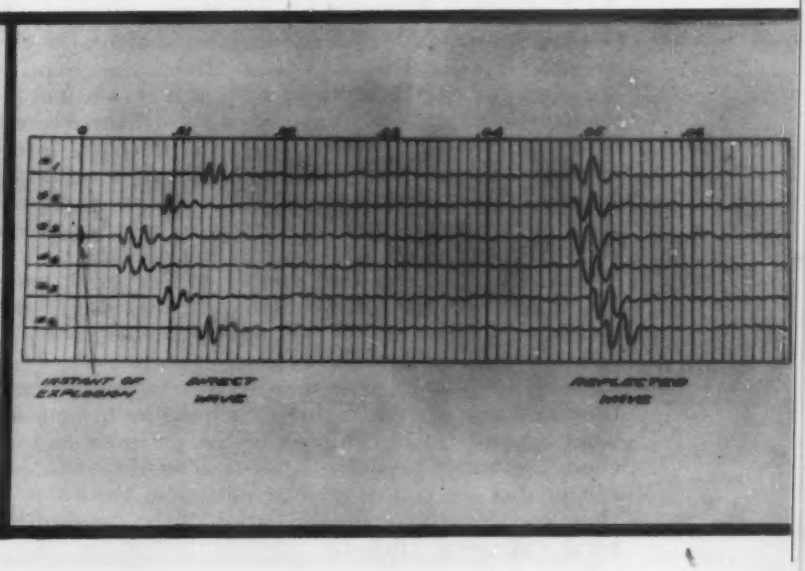


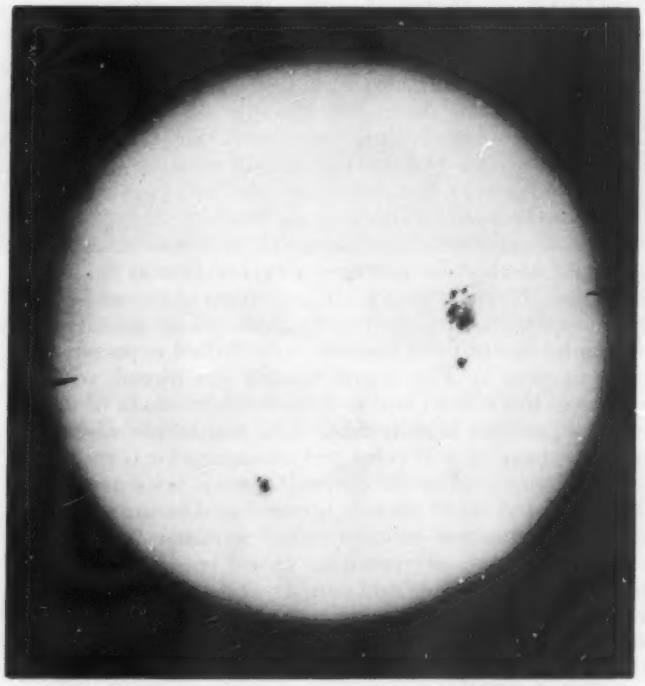
Figure 3



Volcanoes, Mussolini, Disease,

BUSINESS CYCLES, THE NUMBER OF AUTOMOBILE ACCIDENTS IN THE STREETS OF PRAGUE, TECHNOLOGY'S NEW GYM. ALL THESE MAY BE SERIOUSLY INFLUENCED BY THE VARIATIONS OF SUNSPOTS. CAN THESE PERMUTATIONS BE PREDICTED?

AMOS J. SHALER



Sunspots *Mt. Wilson Observatory*

THERE have been published in recent years a large number of works which suggest correlations of numerous variable terrestrial activities with manifestations of solar variations — more specifically with variations in the frequency of sunspots. A great deal of data has been amassed and curves have been drawn which compare the sunspot curve with such diversified variables as radio reception, the Aurora Borealis, all matters pertaining to the weather, earthquakes and volcanic outbursts, mountain-building, ocean currents, glaciation, human diseases, the growth of plants, the number of automobile accidents in the streets of Prague, business cycles, Hitler, the quantity of rabbit fur on the market, wars and revolutions — the list can be made to fill many pages. Of these correlations no small proportion may be accepted as interpreting some physical reality. Some are considered legitimate only by a limited number of people; others are eventually rejected as nonsense even by their authors. The fact remains that the sun has been rightly regarded as the lord and master of the earth since Copernicus evolved his heliocentric hypothesis and must, when it varies in its activity, induce complementary terrestrial variations.

Such knowledge as is discovered concerning these correlations is of great value in helping us to find out what happens to the entropy of the universe, and, of course, valuable in itself. Unless, however, scientists can predict the course of solar variation, the value of these correlations for the prediction of the trend of the earth's affairs is limited.

It is perhaps to the point to mention in passing a little of what is known — or thought to be known — about sunspots. A preliminary observation of the sun's surface will often reveal well defined dark spots of a relative extent comparable to the region of influence on earth of the greatest West Indies hurricanes — some one one-thousandth of the visible area of the hemisphere. Upon further analysis, it is found that the temperature of the spot nuclei is of the order of magnitude of 2,000 degrees, therefore dark only by contrast with the 5,000 degree surface of the sun. The spots generally occur in pairs, both components being at approximately the same heliographic latitude, and the components having the appearance of cyclones rotating in opposite directions. The cause of sunspots is not well understood. No one can say for certain whether they are manifestations of purely hydrodynamical processes, or local thermodynamic alterations brought about by local changes in the absorption of radiation, or some other physical processes. Many theories have been published, but most of them are flatly contradictory.

What interests us particularly here is the phenomenon of variation in sunspot frequency. At times of maximum activity as many as 200 spots can be seen in a month with a small telescope. At times of minimum only a few are visible in a year. The amount of radiation reaching us may vary simultaneously with the spots by amounts varying from two or three per cent in the visible portion of the spectrum to about 20 per cent in the limit of the observable ultra-violet. The shape of the corona, which, unfortunately, we cannot observe except during total eclipses of the sun, changes strikingly between years of maximum sunspots and years of minimum. The appearance of prominences varies also as does that of the spots. There are also evidences of the expulsion of corpuscles in a quantity proportional to the number of sunspots. This is not the complete list of solar variants, but it will suffice for our purpose. The fact that the sun's activity varies has been known almost since the invention of the telescope, but it was not until 1826 that Schwabe discovered a fairly well defined periodicity in the rate of change of the number of sunspots. Subsequent work has shown that the period of the variation averages 11.13 years, but that it may fluctuate between 8 and 16 years.

It is not necessary for us to go into the details of the researches conducted in the early nineteenth century for the purpose of finding out the cause of these variations. It is enough to say that the early investigators held two views: one school attributed the variations to the changing influence of the planets, the other to continuous processes within the sun itself, processes governed in the main by the manner of rotation of the sun. For all practical purposes the astronomers of today are no further advanced in the solution of this problem than was Schwabe. They know a little more about what goes on in a sunspot, and what may cause it, but as far as the reasons for the variation in sunspot

frequency are concerned, their knowledge is still limited — very limited. For this reason most of the studies of solar variation have been based on various methods of juggling the statistical evidence furnished by the assiduous observers of solar phenomena.

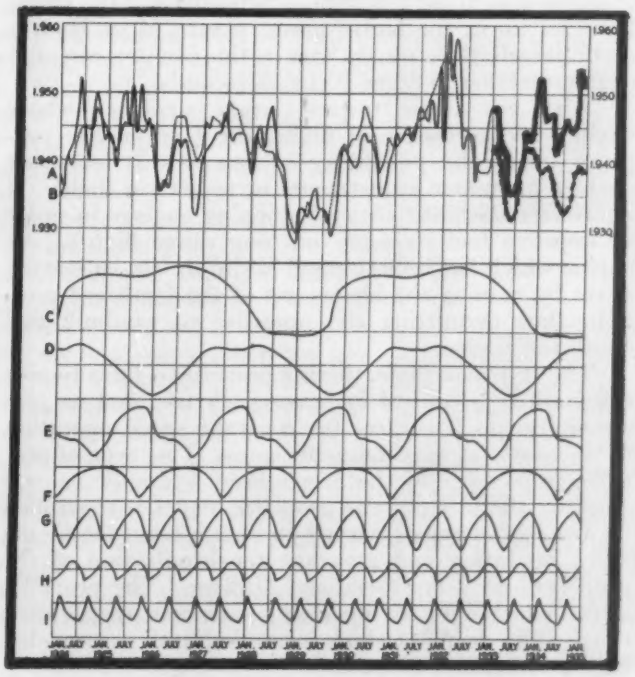
Inasmuch as our knowledge of the motions of bodies in space is very accurate and extensive, it is natural that the theory of planetary control of solar activity should have been formulated during the early part of this century. Many were the attempts to compute planetary configurations, whose influence on the sun could be made to represent fairly well the curve of frequency of sunspots. The procedure was to guess at the relative influence of each planet in raising tides on the sun, or of combinations of planets in raising electric or magnetic disturbances in the solar surface. The next step was to compute the relative positions of the planets and their distances from the sun at any time — in itself no small task. The third step was to draw up a curve containing all this data, or parts of it, and to adjust, as the need presented itself, the amplitudes of various periods to account for loose threads, and finally to present a paper in which could be found on the same graph the synthetic curve and the sunspot curve, far enough apart so that the eye could not possibly accommodate both at once. Occasionally a lucky investigator arrived at a curve which resembled the curve of frequency of the sunspots. Wild rejoicing generally followed, accompanied by predictions of the future trend of sunspots. Though it sometimes took a certain amount of time for the sunspots to depart from the curve dictated for them, they eventually did without fail, and astronomers today seem to think they always will with any given prediction. True, the planets may have some effect in raising tides on the sun, but, according to reliable computations, not nearly enough to account for the energy present in such huge disturbances as sunspots. Again, the planets may have some electric or magnetic effect upon the sun, but again such an effect would be negligible. Some have claimed that the planets' influence may not be direct, but merely sufficient to control the timing of disturbances set up within the sun itself, or to increase by resonance the amplitude of some natural oscillations. There are few arguments to refute these claims, but the consistent failure of the planetary-influence theory to predict the sunspot numbers should suffice for us to pass over this theory without further consideration.

The next method with which hopeful scientists and laymen attempted to bring the variation of solar activity to book was the pure statistical attack. The curve representing the observed variations over many years in the number of spots, or in the intensity of the solar radiation, was broken down by means of a series of analyses, Fourier, periodometer, etc., until there was nothing left but a straight line (or almost straight) and a number of "simple" curves. Then a new curve was synthesized from these, and if the synthesis represented the original data fairly well, it was extended to constitute a prediction of the trend in coming years. Such curves are shown in Fig. 1, taken respectively from Abbot's *Forecast of Solar Variation*, and his *A Group of Solar Changes*. In the first, to all intents and purposes a periodometer analysis, the curves are computed from 1924 to 1933, and extended beyond that as a prediction until 1935. Since this curve was drawn up the actual values for 1933 and 1934 have been observed. These, in Fig. 1, are plotted in heavy continuous line, and the prediction in heavy dotted line. The gradual separation between the two curves can be easily seen. And yet Abbot is recognized as the foremost authority in this type of solar-radiation cycle analysis. The results are the same in other similar studies: the curves fit the data well, but the moment they are made to step into the domain of prediction, they invariably fail to fit. And yet — it is of great credit to the determination of these men — very few of those engaged in this work have abandoned hope of success. But month after month, year after year, even though the sun persists in breaking out at the wrong place, the wrong time, and with the wrong intensity, more and more advocates flock to the banner with newer and better statistics.

There are some, however, who, through laziness or skepticism, have weakened. These people are beginning to believe that the trend of sunspot numbers is governed by chance, and that, aside from using the vague periodicity averaging approximately eleven years, there is really nothing one can do about predicting the course of solar activity. They claim that no process can be of so complex a nature as the sunspot curve if it is governed by well defined laws. And indeed, the irregularities in amplitude, period, and times of minima and maxima would seem to support strongly their argument. Nevertheless, there are certain things about sunspots that keep the researchers encouraged. For instance, there is the well observed fact that at the end of every cycle the magnetic polarity of the spots changes. For spots have a strong magnetic field, observable by its Zeeman effect on the spectrum lines, and, whenever two spots or groups of spots occur together, the one that leads the way across the solar disk is always opposite in polarity to the one that follows. Moreover, the polarities are reversed in the two hemispheres. Now, when a cycle is at a minimum, the whole set of polarities is reversed — a strong argument against chance rule of spot frequency. Yet another phenomenon supports the contention that the cycle can be tied down to a mathematical symbolism, Sporer's

(*Please turn to page 24*)

Figure 1. Analysis of solar variation, 1924 to 1932, and forecast 1933 to 1934 inclusive. A, observation; B, summation of seven periodic curves C, D, E, F, G, H, I of 68, 45, 25, 21, 11, 8, and 6⅔ months, respectively



Hydromatic Full-Feathering Propellers

United Air Lines

THE emphasis on safety in the aircraft industry has probably influenced technical development and design more than any other single element. One of the most recent aids to safety in multi-engined airplanes is the Hydromatic propeller, which combines an available constant speed angle range of 35 degrees with the ability to feather quickly. Feathering is increasing the pitch of the blades to a position where their chord is approximately parallel to the line of flight. The exact feathered angle varies slightly with different blade designs and diameters, but it must be such that the blades when feathered will not windmill in either direction.

By feathering the propeller the pilot is able to stop engine rotation. Since feathering is an emergency operation designed to reduce drag and eliminate vibration resulting from a power plant which has failed, it is essential that feathering be positive and fast acting. In case of power plant failure, much damage may result from the drag of the windmilling propeller and the vibrations set up in the faulty power plant. Most Hydromatic installations on air lines in this country can stop engine rotation in from 10 to 15 seconds.

With the trend toward larger airplanes whose engines are accessible in flight, the Hydromatic propeller offers the possibility of temporarily stopping engines for minor adjustments or repairs in flight. It also offers the possibility of stopping engines in order to improve fuel economy on long range flights. An engine which has been stopped in the air can be started again by moving the blades out of the feathered position, thus permitting the propeller to windmill and crank the engine.

The Hydromatic feathering propeller is built to give full-feathering control for emergency use, and to give automatic pitch control for constant speed operation of the motor at maximum efficiency. This type of propeller makes use of the principle of hydraulic control whereby the pitch of the propeller blades is controlled by a precision type governor to obtain constant engine speed operation and accurate synchronization of the propellers on a multi-engined airplane. The propeller is furnished with an operating constant speed pitch range of 35 degrees, which is ample for all present-day high performance aircraft.

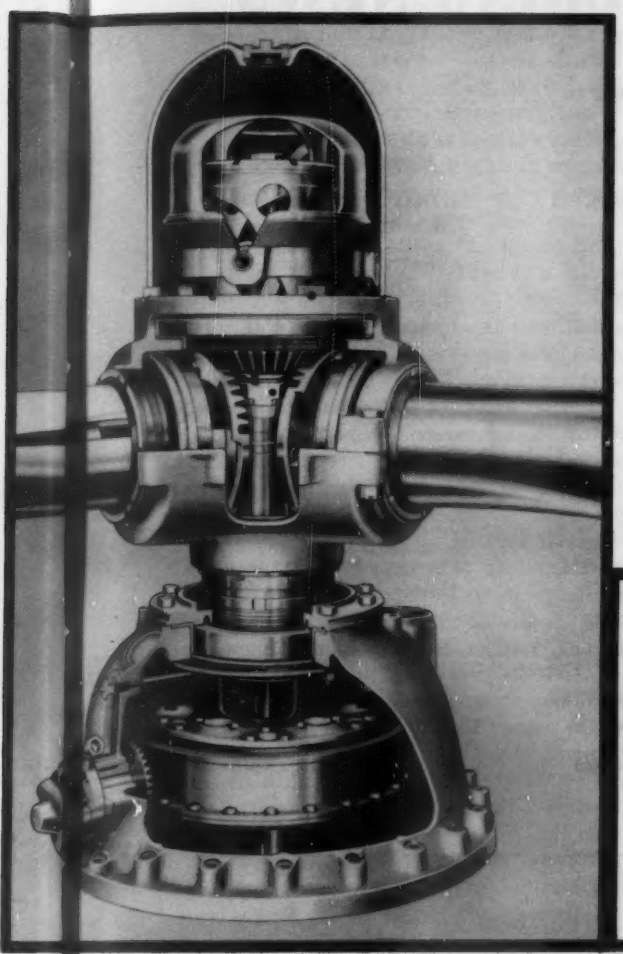
The propeller consists of two major sub-assemblies — the propeller assembly proper and the dome assembly. The propeller assembly proper consists of the spider, barrel, and blades. The structural soundness of this design has been proven by millions of flight hours.

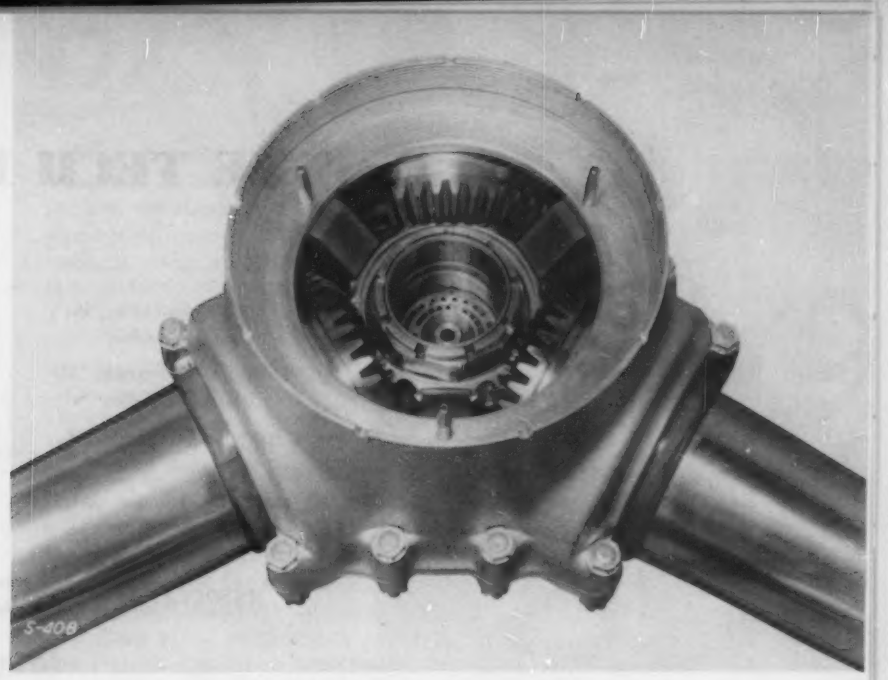
The dome assembly comprises the pitch change mechanism, by means of which oil forces on a piston are translated to blade twisting moments. It consists of two coaxial cylindrical cams. The outer cam is stationary, being rigidly fixed to the propeller hub. The inner cam is attached to the stationary cam by means of ball bearings which transmit the gear reactions and the piston oil forces. This inner cam has an integral drive gear which meshes with the gear segments attached to the butt ends of the blades. The roller bearings which operate in the cam slopes of both the rotary and stationary cams are supported at either end by the double wall piston. The two cams and the piston are enclosed in a spinner-shaped dome. This whole assembly is fastened to the front of the propeller barrel by one retaining nut.

On the steep slope of the cams the piston has a high mechanical advantage which insures accurate constant speed operation. As the propeller piston moves out or in, the blades assume a higher or lower pitch. Oil under pressure from a constant speed control unit acts on the inner side of the propeller piston. This force tends to move the propeller toward a higher pitch. When the constant speed unit permits the oil on the inner face of the piston to drain, the centrifugal twisting moment of the blades decreases the pitch. Supplementing this blade centrifugal moment is oil under engine pressure at the forward side of the propeller piston. During constant speed operation this engine oil is always open to the engine system and acts as a resilient force.

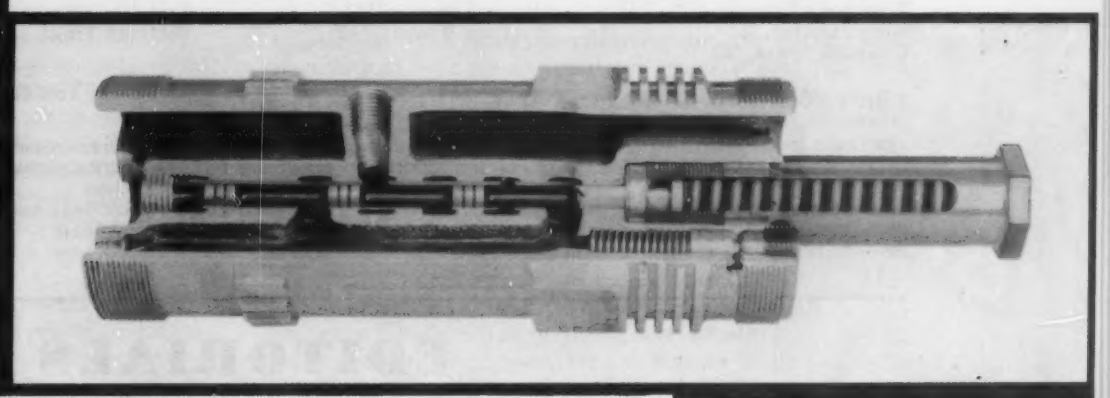
The constant speed control is a governor of the centrifugal flyball type. It is mounted on an engine drive, and, therefore, its rotation is directly in proportion to that of the engine. The force of the flyballs works against a spring load which can be regulated by the pilot, thereby permitting the pilot to select any engine rpm desired. If there is a tendency for the engine speed to increase, the governor flyweights move out, lift a pilot valve, and oil under pressure is admitted to the inner side of the propeller piston, so that the propeller blades are moved to a higher pitch, thus holding the rpm constant. The reverse action is true if the engine rpm should decrease. The constant speed control unit incorporates a gear pump which furnishes oil under 180 to 200 pounds pressure. Oil passages and mounting for this control unit are standard on the majority of present-day engines.

As an insurance against accidental feathering, a force of approximately 400 pounds per square inch is required to operate the propeller beyond the elbow in the cams. The change in cam slope has an added advantage of providing a large blade angle change for a relatively short piston movement, which assures quick feathering.





Photographs courtesy Hamilton Standard



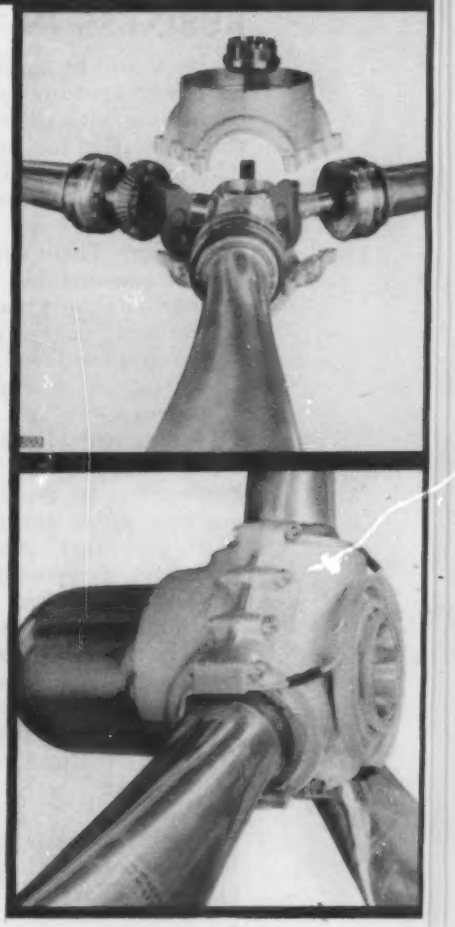
To feather, oil under 400 pounds pressure is admitted to a connection at the base of the constant speed unit. The operation of the propeller in feathering is exactly the same as when it is changing to a higher blade pitch, with the exception that it continues to move until the high pitch stops are reached. When the high pressure oil is admitted to the governor unit base, it operates a sliding valve which shuts off oil from the constant speed control unit proper.

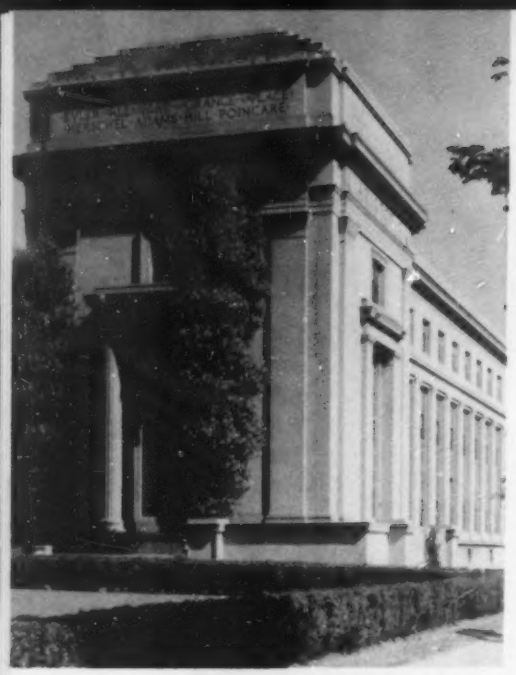
In order to unfeather the propeller, it is necessary to direct high pressure oil to the forward side of the piston and open the rear side of the piston to the drain position. This operation is accomplished by a distributor valve, which is attached to the forward end of the engine propeller shaft. During constant speed (and feathering operations) this distributor valve directs engine oil pressure to the forward side of the piston, and governor oil pressure (or feathering oil pressure) to the inner side of the piston. When oil under a pressure of approximately 600 pounds is applied, a piston in the distributor valve is actuated against a spring force, and in sliding forward it realigns the parts so that high pressure oil flows to the forward side of the piston and the rear side is open to the engine. The distributor valve, therefore, is actuated only during the unfeathering operation.

The feathering and unfeathering oil pressures are furnished by a source independent of the engine. This source can be either an electric driven motor pump, using engine oil, or the plane's hydraulic system. United Air Lines have adopted the former, and American Airlines the latter type of installation. To feather, the pilot merely pushes a button or lever. As soon as the propeller is completely feathered, an automatic pressure cutout is actuated to stop further operation and prevent the pressure from building up to a point where the propeller would unfeather. Thus, the pilot is entirely free to concentrate on other duties during the emergency. To unfeather, the pilot merely holds in the button or lever and pressures build up high enough to permit unfeathering. When the propeller is unfeathered as far as is desired, the pilot releases the button or lever and the constant speed unit assumes control.

The Hydromatic propeller introduces several new features in propeller design. The entire operating mechanism is pressure lubricated. This greatly reduces wear and any tendency toward corrosion, as well as eliminating the necessity to grease the propeller. Airlines are operating Hydromatics 400 to 500 hours between overhauls.

The automatic control afforded by this ingenious combination of simple mechanical principles keeps the engines of airplanes operating at maximum efficiency during climbing, descending, or normal flight conditions, and affords the pilot an entirely new factor of safety for which there is no substitute.





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EDITORIALS

BUSINESS IN THE SUN

He would be considered the most gullible of economists who ventured to suggest that his subject had any connection with the studies of the solar physicist. Yet this suggestion has been made, and the possibility of a relationship existing between economic phenomena and the variability of the emanation of the sun has long been considered one of the questionable theories of economics. There can be no doubt that this relationship is questionable, but it has persisted and its very persistence should make one consider it yet again before relegating it to the realm of the febrile astrologer.

Sir Stanley Jevons was the first to suggest the idea. He attempted to correlate solar phenomena with the growth of plants and the yield of the agricultural world. In this manner, through the medium of agriculture, he claimed that solar activity controls the business cycle. Sir Stanley has been proved wrong. Solar activity has no measurable effect upon agricultural yield; it has much less effect upon the price of the individual crop. Therefore, every economist will tell you, there can be nothing to the idea.

In all probability they are right. More likely than not, the theory can be ascribed to the incurably romantic imagination of man, which will attempt the most inconceivable tasks in order to find connection between anything and everything. But they are not right in so dismissing the problem because Sir Stanley Jevons has been proved wrong. There may be no marked connection between agricultural yield and sunspots; there is perhaps even less evidence to suggest relationships between solar activity and crop prices; yet there still exists a remarkable similarity between the curves of sunspot numbers and the ups and downs of the economic cycle.

There are many reasons why this could be so, and they are reasons which deserve further consideration and study. It has been suggested by many men that the influence of the sun on social institution is more direct than had previously been supposed possible — that the connection link was not agriculture but man himself. Some investigators have mentioned the probability that variations in the solar rays affect man physiologically and, ultimately, psychologically. Others have thought that the sun's role in changing the degree of ionization of the atmosphere has some effect on the psychological makeup of man. And these are but a few of the many connection links which may be adduced to account for the supposed relationship between man and his sun.

The study of solar-terrestrial relationships is yet in the period of its conception. Nothing definitive has been accomplished. Perhaps nothing will be accomplished for many years to come. We cannot fail to take into consideration, however, in a time when the leading men of science are stating that the cul-de-sac has been reached, that many avenues may present themselves to the investigator in the field of solar-terrestrial relationships.

HUMAN ENGINEERING

For two years a small group of Tech men, now numbering twenty-three, have worked among the underprivileged boys in Greater Boston, endeavoring to do their part to make these boys good citizens, and to give them a taste of the better side of life. There is very

little that these men have been able to do, small in numbers as they are compared to the thousands who need help, but they have made a grand start.

These men have come in contact with the most abject of conditions. They have found the mother who has six or seven children and who cannot take care of them adequately, the mother who does not care about her children, the father who is unemployed or who is a drunkard, and they have seen economic conditions at such a low level that the children living in those neighborhoods never have a chance to become good citizens.

Young people are easily influenced by men and women that they admire. Since this is true, it is felt that a good influence is as easily impressed as a bad one. Therefore these boys could be, and are being, helped immensely if college men would come in contact with them and give to them a little of their own personalities. The Tech man has been found to be particularly fitted for this kind of work because of the training in dealing with facts that he has had, because of his adaptability to situations as he meets them, and because of his knowledge of technical and scientific facts, such as would interest wide-awake boys.

The greatest good, however, comes to the Boys' Worker himself. He learns about human nature, about satisfying human wants, adjusting himself to strange surroundings and people, how to deal with those people, and, above all, his character is improved. The boys with whom a worker deals are, of necessity, sharp eyed. They can detect a false character quicker than can a grown man. It is certain that any man who can deal with these boys will certainly be able to deal with men when the time comes.

The following quotation from a prominent Boys' Work director expresses the views of all prominent business men: "In traveling through the world and meeting a great number of people, I have yet to find one important, successful person who did not tell me that the greatest pleasure in life came from doing things unselfishly for others."

J. H. GREENBERG

"STERILAMP" FOR SANITATION

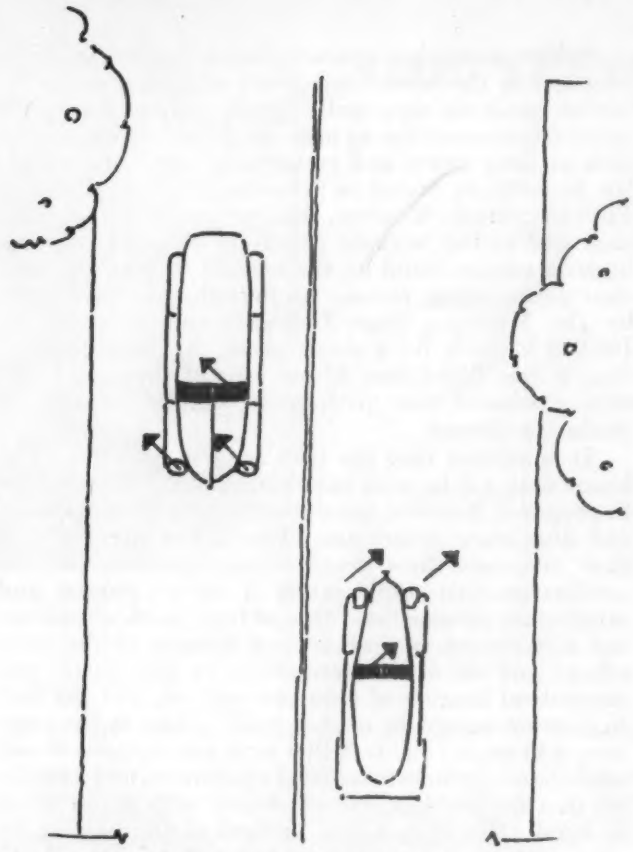
Most States, Massachusetts included, have stringent but ineffective laws governing the sterilization of eating utensils used in public places.

Public protection against disease has made great advances in the last twenty years with modern sterilization methods supposedly giving ample protection against disease-producing bacteria. Public eating places, such as drug stores and restaurants, are required by law in forty-six States to "sterilize" their equipment. The fact remains, however, that equipment is not sterilized, and almost without exception disease-producing bacteria can be found on the utensils of even the first class public eating places. An investigation carried on by the Michigan State College found as many as 100,000 bacteria on a single glass. At Montgomery, Ala., it was found that 40 per cent of the soda fountains examined were pathogenic, that is, capable of producing disease.

It is evident that the laws are not enforced. The blame does not lie with enforcement officials, as might be supposed, however, nor does it lie with the restaurant and drug store proprietors. The fact is that up to a short time ago there were only two good methods of sterilization that would result in fairly complete and satisfactory sterilization. One of these methods, chemical sterilization, was eliminated because of the toxic effects, and the other, sterilization by live steam, was impractical because of economic reasons, and the fact that steam cannot be used in small places in the summer. Add to this the fact that air-borne bacteria would immediately re-infect sterilized equipment, and you can see that the problem was unsolvable with the methods at hand. However, a new method of sterilization by ultra violet rays, recently developed by Dr. H. C. Rentschler and Dr. R. F. James of the Westinghouse Company, promises a way to end the difficulty. The "Sterilamp," described in the November TECH ENGINEERING NEWS, can be installed in series along the inside baffles of soda fountains, etc., and gives 99.99 per cent sterilization up to the time of use. The lamp operates only four or five degrees above room temperature, thus adding no discomfort to the patrons or the employees. The equipment need only be exposed to the lamps for one or two minutes to secure maximum steriliza tion.

This new sterilization device is within the economic reach of everyone. The installation cost will be greater than the cost of a month's supply of soap and water, as it is used at present, but the increase in safety offered to the public will far overbalance the cost.

Valve assembly *Jenkins Valve Corporation*



POLAROID ON THE HIGHWAY

One of the most seriously considered applications of polarized light at the present time is its use in automobile headlights. Polaroid, a new sheet-polarizing medium, furnishes a convenient means for obtaining polarized light which may be utilized in attaining Glare Control on the highway by the following artifice, first proposed by Westinghouse's Dr. Chubb: *Light from the headlamps of a car is to be polarized so that it vibrates in a plane at forty-five degrees to the vertical from the direction of travel, as in the diagram. An analyzer, through which the driver looks, is to have its principal plane in a parallel direction. Then the light, if it is reflected from objects on the road without any change in polarization, returns to the driver diminished only by reflection losses and the absorption losses in Polaroid.*

If a driver of a Polaroid-equipped car meets another car so equipped on the highway, he experiences no glare, since the situation is analogous to forcing one picket fence through another, at right angles. The scheme is quite effective and appears to be the ideal solution. Certain difficulties present themselves, however, and these become apparent in the following analysis.

Light from the headlight bulb in becoming initially plane-polarized is reduced, at least, by a factor of two, since we throw away all the components in one plane. The subsequent reflection then takes either of two forms: (*a*) Reflection from shiny metallic parts, as a rear glass, or a chromium-plated bumper, in which the plane polarized light is reflected without any depolarization or "unscrambling." Thus, the driver sees the light from his headlights reduced, perhaps only by a factor of three, considering eight per cent air-glass surface losses, and ten per cent color absorption in the Polaroid. (*b*) Reflection from diffuse objects, such as textiles or rough surfaces. Here the light is depolarized by varying amounts, and the reducing factor varies to a maximum of six. This latter type, after much dispute, was considered in the illumination laboratory. The work was done by putting various samples of cloth on the laboratory reflectometer, and directing substantially collimated plane-polarized light at the sample; the reflected light was then analyzed by a Polaroid disk. If no variation was observed by rotating the analyzer, then the sample was said to depolarize the light, since it had lost its polarized qualities.

We encountered difficulties, since the work was done with a visual-matching photometer, which made quantitative measurements. Recently, the machine has been improved, so that now the work can be done by photoelectric means. However, the results we first obtained are indicative of what can be expected. The depolarization of light reflected from cloth was found to depend on a number of factors. One, which is somewhat strange, is that the "scrambling" depends on the color of the cloth. Dark materials were found to result in little depolarization, varying from about 20 per cent for one direction of polarization to 50 per cent for a perpendicular direction. Light clothes, on the other hand, showed a range of 50 to 90 per cent for the same cases.

The reason for this behavior is presumed to be that the "scrambled" components are absorbed in the dark material, while in the light material they are reflected back, resulting in a "net scrambling." Thus, under the projected scheme, light textiles would have their normally bright reflections diminished, and dark clothes would stand out against a dark background.

The results of this investigation are of value, since they show how polarized light will behave in the projected installation. It is advantageous that the dark textiles behave as they do, since the contrast between cloth and background will be raised when this scheme is employed. However, this particular problem is but one of a number that must be solved before the system is actually put into practice. One is that the increased candlepower of the headlamp is such that it becomes an economic, as well as engineering question of just how to build up the electric generating capacity of automobiles almost overnight, in the event that legislation requires automobiles to use polarized headlights.

In order for the plan to work well, it is quite important that the use of polarized light become universal at one time, for unprotected drivers would be at a disadvantage, if this were not so. A factor that is in Polaroid's favor is, however, that as glare is eliminated, visual accuracy for the same road illumination is substantially increased, so that, perhaps, the headlight candlepower will not have to be built up as much as the foregoing figures would indicate.

Another is that under average conditions, with the candlepower of headlights perhaps trebled, the glare caused to pedestrians is a serious problem. It has been suggested that Polaroid glasses be adopted as standard equipment for "jay walking," but this is not to be accomplished without considerable difficulty.

Since the scheme is without use during the daylight hours (for the case considered), the analyzing screen is presumably dispensed with during that period, and it is speculative as to how foolproof a device will be to place a Polaroid screen in and out of the field of vision. Various sources have advanced the belief that it is contrary to human nature to expect a driver, even at night, to interpose a polarizing screen in his field of view, in

the event that it will reduce the brightness of ordinary objects by 50 per cent. Dr. Chubb suggests that a "peek-under" screen, like a sun visor, be employed, but this question will bear more investigation.

A factor that deserves consideration is the departure from level travel on a high-crowned road, where the outside wheels drop lower than the inside ones, due to a low shoulder. The Polaroid screens in this case are not perfectly crossed, and as a result some light is transmitted. Since the apparent brightness varies as the square of the cosine of the misalignment angle, quantitatively not much light is passed, yet the eye perceives these small variations and glare does result. While very high-crowned roads are not common, the factor nevertheless merits attention.

The Polaroid Corporation, however, has a scheme to avoid this difficulty, and they plan to do this by using circularly polarized instead of plane polarized light. In this system, a quarter wave plate, of a plastic material, is applied to the outside of the initial polarizer, and the result is that the tip of the electric field vector appears to travel in a corkscrew manner. The analyzer or viewing screen (which is also preceded by a quarter wave plate whose azimuth is on an approaching car) then tends, in effect, to give the beam a counter-twist, and the net effect is no transmission of light. The advantage then acquired is that the system works independent of the azimuth of the viewing and polarizing screens. This then is the most elegant means of accomplishing the desired result; yet it will work theoretically only for essentially monochromatic light. In view of this, its additional cost, and the generally small effect which it corrects, the scheme seems hardly practicable for the present.

Considering the problem as a whole, it is readily seen that it is by no means a simple one, and that the legislation required to place safety glass as a mandatory requirement on automobiles was a simple matter compared to this projected scheme. Our research carried on to determine the magnitude of depolarization of light as reflected from cloth is merely a small step in view of the development work necessary to attain a convenient scheme for eliminating headlight glare. The importance of this work, however, is inestimable in view of current accident figures for night-time driving.

LEONARD MAUTNER, '39.

WING PROBLEMS

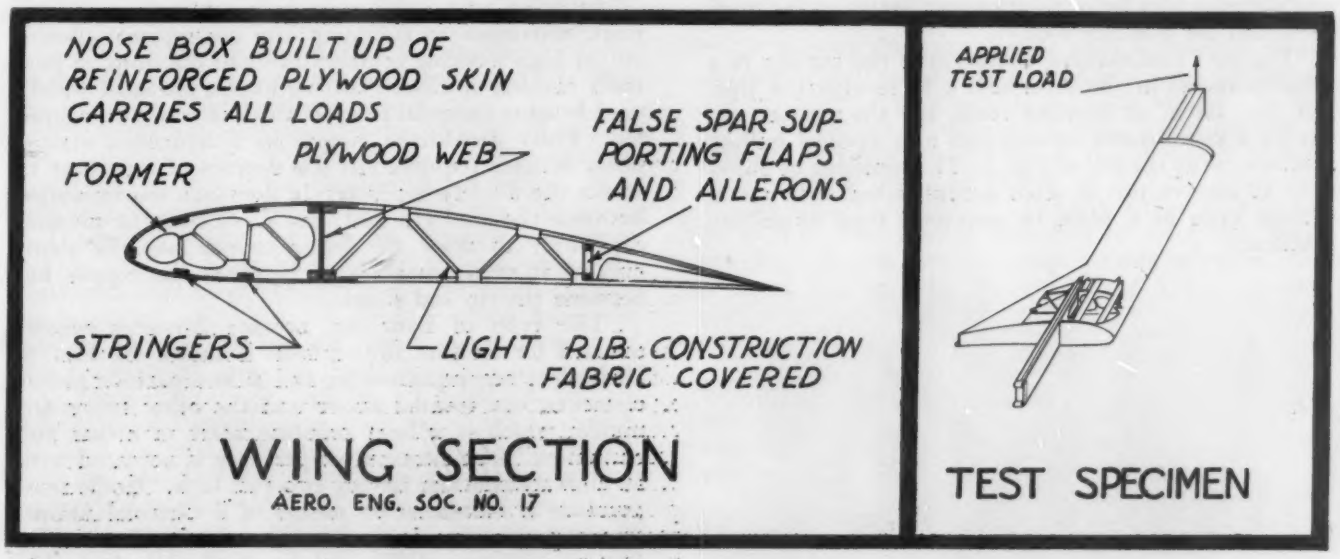
Rapid expansion and development today in the aviation industry is causing a constant evolution of new problems, forcing the engineer to keep abreast by unusual refinement of engineering technique.

At the Institute men are getting invaluable experience of this type through the activities of the Aeronautical Engineering Society. An example of this is one of the problems facing the members at present. The club is in the process of designing a high-performance sailplane which when constructed should rank among the best in the world. The design of the wing calls for such excellent aerodynamic qualities that, employing the present day approved construction methods, the weight will of necessity be rather great. With this in mind a new type of wing construction will be investigated by Paul Snadorff and Andrew Fogliano as an undergraduate thesis.

The problem is to design and construct a torsion box spar of the type shown in the accompanying sketch, and to check some method of stress analysis which when carried out will give a satisfactory structure. This spar deviates from the rectangular box spar in that it follows the outline of the airfoil section and actually is the wing forward of the vertical web. The limitations of the beam theory are such that this spar is outside ordinary stress analysis methods. It may be interesting to note that the engineer is trying to simulate the ideal structure that nature uses every day; the skin of a beetle whose skeleton is where it should be, on the outside.

The best approach to a good solution of this problem is the one used in industry today. A nine or ten foot test section of this spar will be built and loaded to failure, keeping a careful check of deflections at all times. In order to forestall the event that the test section be so badly over or under stressed as to make the results worthless, some rough calculations of the expected stresses will have to be made. Several approximate methods of analyzing this type of structure are available, but as yet none of them have been proven and all are equally approximate.

Thus the test section of the spar will be built, designing the stiffeners, webs, fillet blocks, and nose formers by the best of the approximate methods. By choosing a section of the spar at the root the design of the root



fitting can also be incorporated. In the actual test the spar will be fastened to a convenient wall by the root fitting and the load applied by a jack in such a manner as to produce the maximum bending moment, shear, and torsion that the wing will experience.

The proof of the structure will be done in the presence of a Department of Commerce inspector in order that a license may later be obtained.

SINTERED CARBIDE TIPPED TOOLS

(*Continued from page 7*)

results of method of production and heat treatment will profoundly affect machinability, the magnitude of the resultant cutting forces, and mechanism of chip formation and removal. These factors will also be influenced by the present or proposed machining practice insofar as cutting speed, feed or chip thickness, and depth of cut or amount of stock removal are concerned. The desired accuracy, finish, rapidity, and economy of machine production will also dictate the requirements of the proper grade of sintered carbide for the purpose.

As previously mentioned, the carbide tool tip is sawed from a pressed and partially sintered compact and then sized and shaped before final sintering. The presintered material is fragile, easily broken, and highly abrasive, but, with care, it can be machined and ground with comparative ease.

The first unit operation in the manufacture of carbide tipped tools is the preparation of the steel shank. For a single point lathe tool this takes the form of merely cutting a proper length from a rolled steel bar of desired cross section. More complicated forms require forging, shaping or turning in a lathe, and milling. Inasmuch as different kinds of grinding wheels are required for the most economical grinding of the carbide and steel shank portions of many tools, it is common practice to deliberately make the tool shanks slightly undersize, permitting the separate grinding of the carbide tool tips which will, in consequence, slightly protrude. This practice is confined to the regions of the tool shanks immediately adjoining the tips. Obviously, the part of the tool shank which is joined to the machine tool or held in the tool holder must be accurately sized to provide a neat and snug fit to insure both rigidity and accurate register or positioning relative to the work piece and the machine tool.

The next tool making operation is the cutting of a suitable recess in the steel shank to receive the tips. For flat, lathe, or forming tools, the tip recesses are cut by a small diameter end mill in a vertical milling machine, as at the left of Fig. 2. The recessing of fluted tools to receive tips is often accomplished with metal slitting saws in a plain or universal type of milling machine.

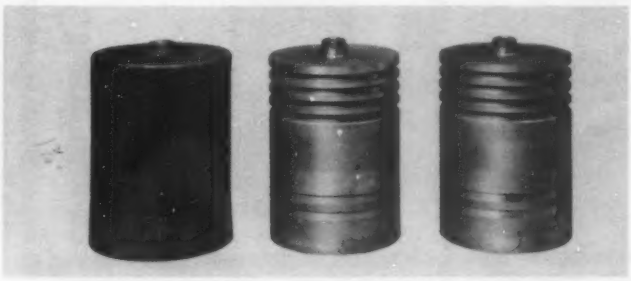


Figure 12. These cast iron pistons are rough turned, faced and grooved with sintered carbide tools

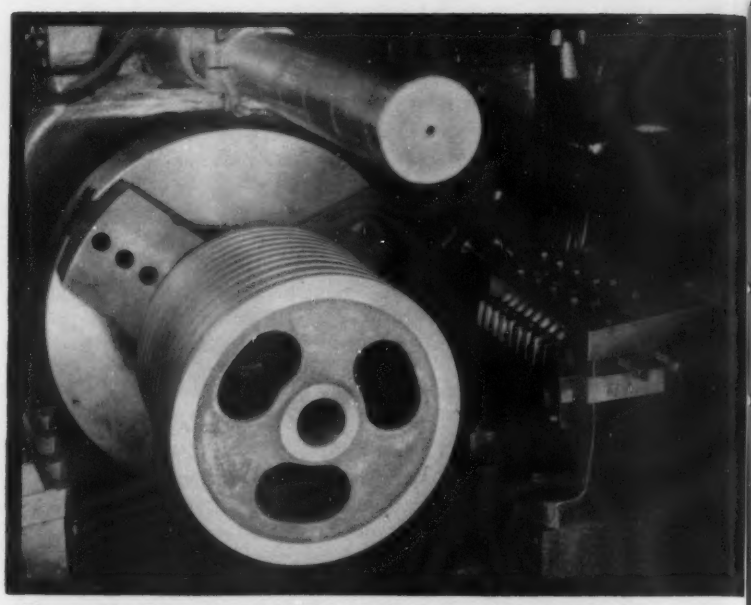


Figure 10. Rough and finish turning, grooving and facing a Potter and Johnson cam drum

The tips are hand ground to an accurate and smooth fit in the tool shank recesses, as in the center of Fig. 2. At the right, the tool, after brazing, is shown. Maximum surface engagement and close fit are attained by grinding shank-mating surfaces of the tips as flat as possible, and flank engagement is assured by eliminating corner interference through the grinding of fillet radii along the lower tip edges. Steel filler blocks and wear strips which are to be brazed in place with the Firthite tips are also carefully fitted in the shank recesses. The wear strips are made of alloy steel which will air harden as the tool is air cooled from the brazing temperature. The thickness of the brazed joint may be safely ignored since it rarely exceeds 0.002 inch. In fact, the reason for the close fit between tip and shank lies in the fact that the strength of the file of intervening brazing material is greater for thin than for thick films.

Just prior to the brazing operation the tool tips and shanks are thoroughly degreased and cleaned in carbon tetrachloride and hydrochloric acid.

In order to provide necessary strength of brazed joint, resistance to softening and consequent squeeze out at high working temperature and ductility to partially cushion or absorb cutting forces, the most widely used brazing material is 0.003 thick electrolytic copper foil. Fully deoxidized copper in a hydrogen atmosphere furnace requires but few degrees of superheat to attain the fluidity necessary to flow into the interstice between the tool tip and shank. A neat fit permits capillarity to draw the liquid copper into the joint, making it quite unnecessary to place the copper foil between the tip and shank.

The type of hydrogen brazing furnaces recommended for Firthite tipped tools is shown in Fig. 3. Heating is accomplished by two silicon carbide globar elements, one located above and the other below the muffle, which is a heat resisting alloy of nickel and chromium. The furnace temperature is adjusted with an auto transformer having two volt taps. Muffle temperature is measured by means of a Chromel-Alumel thermocouple type indicating pyrometer. The smaller furnace with two muffles will braze all tools up to 1¼ inches square, while the larger furnace will accommodate a tool shank 2 x 4 inches. A rear view would show

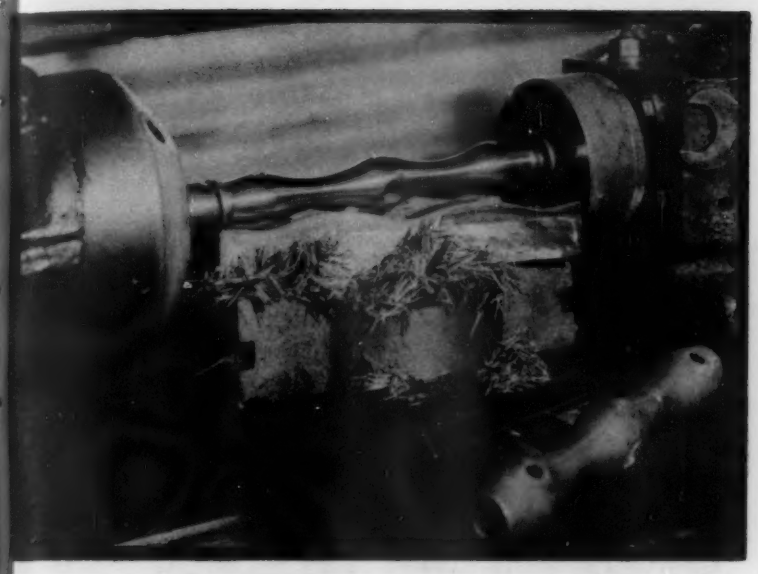


Figure 11. Carbide tipped skiving tool, forming a brass sink fixture

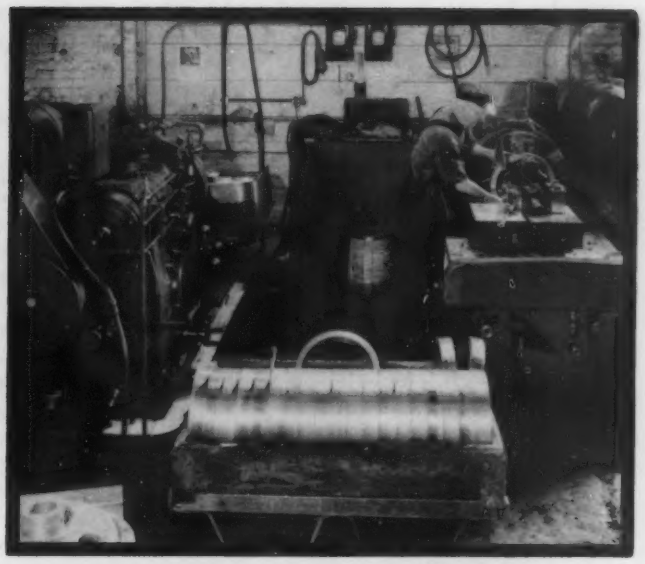


Figure 13. Turning, facing and boring steel bull gears with sintered carbide

the hydrogen tank, regulator, and manifold for providing a hydrogen atmosphere for the brazing zone of each furnace. The specifications of the furnaces are shown in Table II. Fig. 3 is a general view of the brazing room at the main works in McKeesport, Pa.

The tool shank is preheated with flux, to provide a slag for dissolving any oxides which may result from the partial pressure of oxygen in the furnace atmosphere, which also operates to increase the fluidity and spread of the copper brazing material. The Firthite tip is placed in the shank recess with tongs, and a folded parcel of copper is placed on top. When the copper melts and flows completely, the tool is withdrawn from the brazing zone and pressure is applied to the Firthite tip to squeeze out excess brazing material and any flux or air bubbles which might otherwise be entrapped between the tip and the shank. After cooling in air or in powdered graphite the tool is ready for shot blasting and grinding. In addition to being supplied finish ground and sharpened ready for use, Firthite tools can be purchased brazed only. The purchaser furnishes a recessed tool shank ready to receive the sintered carbide tip which the supplier furnishes and brazes in place. On milled and brazed tools, the supplier furnishes the carbide tip brazed to a steel shank. In both cases the user saves by doing the grinding.

The great hardness and density of sintered carbide make grinding to shape upon ordinary emery or corundum grinding wheels an obvious impossibility. It is necessary to employ special grinding wheels in which the abrasive grains are graded crystals of silicon carbide held in a vitreous matrix of such controlled brittleness that when the particles have become dulled the increased attrition will dislodge them from the grinding surface, causing the wheel to wear relatively freely, constantly exposing fresh, sharp grains to grind away the hard carbide tool tip. In addition, the so-called diamond wheels have been developed for grinding hard sintered carbide tips to form keen cutting edges and smooth faces. Crushed and graded diamonds are used to impregnate either molded synthetic plastic materials, such as bakelite, or cast metals, such as aluminum. Diamond wheels possess the ability to grind even the hardest grades of carbide easily and rapidly without suffering the rapid deterioration through wear which characterizes the abrasive or silicon carbide wheels.

Grinding wheels are available for grinding carbide tools in a wide selection of shapes, sizes, grits, types of bond, and kind of abrasive classified as to purpose and adaptability to certain standard grinding machines.

Rapid rough grinding requires coarse grit, open structure, softbond, cool, and free cutting wheels. Diamond wheels are used on surface, universal tool, and cutter grinders but rarely for roughing shank tools on an offhand grinder. A true, steady wheel spindle of substantial proportions running at the proper speed in large, snug bearings is needed; therefore a massive and rigid machine with driving power to avoid slowing down under load is indicated. Effective wheel dressing to maintain truth and avoid bumping is required. Dulled abrasive grains not thrown out of the wheel by natural wear must be dressed off. The surface being ground should be flooded with coolant. The tool must be correctly presented to the wheel with either line or minimum surface contact. For ultra rapid stocking, a grinder carrying the tool along a tangent to the periphery of a plain wheel can be used to advantage, as in this type of machine (Fig. 4).

If volume does not justify such a machine, minimum surface contact can be realized by grinding on the periphery of a large diameter plain wheel. The tool must be rocked from side to side, while moving it rapidly and continually across the grinding surface. And tilting it from end to end, so that the shank and tip are ground alternately. The shank clearance should be greater than the tip clearance in order that finish grinding on the face of a cup or ring wheel in this style of grinder (Fig. 5), to produce a flat, straight clearance flank under the cutting edge, can be confined to the carbide itself.

It is vitally important that the tool be moved relative to the wheel as rapidly and as continually as possible. The carbide tips will crack despite the use of a diamond wheel if the wheel is permitted to dwell in one spot.

Grinding can be greatly simplified and minimized by careful design and planning before brazing. Contrary to traditional tool steel practice which involves the leaving of excess stock to eliminate surface decarburization and high heat hardening distortion, carbide

tool shanks can be machined and preformed close to finish size before brazing. Tips can protrude slightly from intentionally undersized shank surfaces. Grinding then involves only sharpening carbide tipped cutting edges and sizing of shanks to fit tool holders or driving sleeves.

The grinding of a large number of a limited variety of designs can be conveniently handled on a type of grinder having a roughing and finishing wheel and a diamond lapping disc. Special angle fixtures are used on protractor tool rests. The machine is also available with two wheels without the diamond lapping disc.

Tools for forming, skiving and grooving can be surface ground to advantage in a currently available surface grinder which has a hydraulic table traverse mechanism capable of speeds up to 125 feet per minute. Such precision tools can be rapidly and accurately finished in this type of tool and cutter grinder (Fig. 6). This machine is also well suited to the sharpening of inserted blade face mills. Rapid, easy hand reciprocation of the work under the wheel is afforded by a roller chain table mounting as shown in this view.

Lapping is essential on the face, lands, and flanks directly adjoining cutting edges. All tools should be lapped, even those intended for roughing. An initially smooth tool-work surface measurably postpones wear even on roughing tools. Unrelieved lands on precision grooving tools and reamers must be precisely lapped. Conventional ring laps charged with diamond dust in olive oil are used. Skiving tools and in general all forming tools should be diamond wheel ground and then hand lapped for best results.

Purchasers of grinding equipment today can choose machines and wheels to fit their own special requirements from a wide selection of readily available types and qualities at prices in keeping with the class of service and budget or size of appropriation at their disposal. The small shop today need not pay a premium in the form of a large investment for special grinders and costly wheels to enable it to use carbide tools. Small, light duty grinders of the pedestal and of the bench type are available at low cost.

Cutting tools must be precisely made to do the precision work required by modern manufacturing which embraces selective assembly and the even more exacting requirements of the mass production of interchangeable parts. In consequence cutting tools must be made to rigidly observed tolerances and carefully checked to prove their accuracy. In addition to templates and conventional gauges, important dimensions must be measured with dial micrometers, magnifying gauges and precision measuring machines such as super micrometers and tool-makers' microscopes. The contour of forming tools having intricate cutting edges must be examined at high magnification and compared with master outlines in contour projection machines.

Perhaps the most interesting and certainly the most practical phase of sintered carbides is their scope of application and the benefits conferred by their use.

Firthite sintered carbides, by virtue of their superlative resistance to abrasive wear, find wide use in tools for cutting metals and abrasives. Firthite is also used for wear-proofing machine parts and gauges against abrasion. In fact, Firthite should be considered for any application requiring extreme hardness coupled with great compressive strength.

In the mass production shop engaged in repetitive manufacture of interchangeable parts, the need of Firthite is obvious and vital. Rapidly moving production and assembly lines can be paced only through use of tools of maximum cutting ability and long tool life. Firthite tools retain their keen cutting edges for long periods even at very high cutting speeds and enable automatic machines to continue to produce accurately sized and smoothly finished pieces without frequent shutdowns and interruptions for tool changes.

Mass production shops require and use largely single purpose machines which are specially designed for carbide cutting tools.

In the job shop manufacturing in relatively small lots, the use of high strength materials is often essential. Firthite answers the need for cutting tools which will readily and economically machine such tough, hard and abrasive materials. Sustained accuracy and high quality of surface finish are insured through the use of Firthite.

Today we may quantitatively decide which cutting tool material is the most economical for a particular machining operation by applying the equation

$$Cp = \frac{Cc}{Pg(Ng+1)} + \frac{GtGrK}{60Pg} + \frac{Ch\ Mr}{60Pg} + \frac{Tp\ Mr}{60}*$$

in which

Cp = sum of tool, machine and labor cost per piece.
Cc = purchase price of tool in dollars.
Ng = number of grinds in life of tool.
Gt = time to grind in minutes.
Gr = rate charged for grinding per hour.
Ch = time required to change tool.
Mr = machine rate in dollars per hour.
Tp = average time required per piece. 60/net produced/ hour.
K_s = factor equal to number of grinds divided by the number of grinds plus one.

This equation includes overhead and depreciation but not interest.

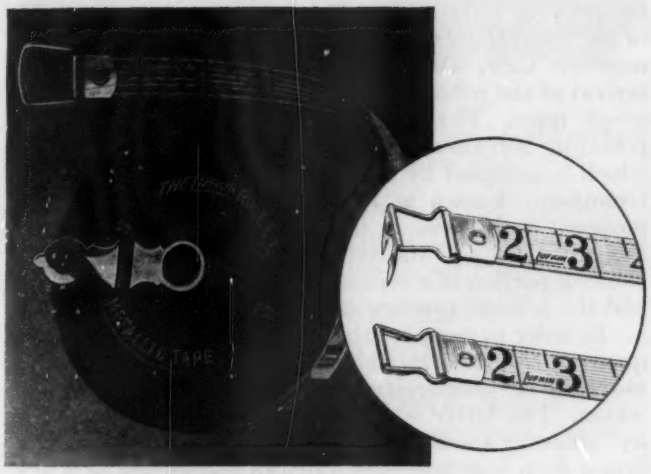
In conclusion, the following selected examples of sintered carbide tool performance compared with previous cutting tool materials serve to illustrate the ratios of tool life and production increase which may reasonably be expected in the machining operations on the materials listed.

Fig. 7 shows a Model 10 Sundstrand Auto turning a cast brass valve insert. Rough turning removes 3/32-inch cut with 0.015 feed at 585 feet per minute and finish turning involves a 1/64-inch cut at 980 feet per minute with 0.005 feed. Floor to floor time is 1.41 minutes. The cut is intermittent due to the transverse slot. The finish produced by the carbide tool makes grinding unnecessary.

Next a Potter and Johnston cam drum is being made on a Model 7D (Fig. 10). Rough turning removes ¼-inch cut with a feed of 0.057 at 175 feet per minute, and finish turning involves a 1/32-inch cut at 300 feet per minute with 0.036 feed. Grooving and facing is done at 300 feet per minute with 0.010 feed. 85 pounds of semi-steel are removed in 11 minutes. The ten ½-inch grooving tools alone cut 50 pounds with a total cutting edge engagement of 5 inches (Fig. 24).

Fig. 11 shows a 10¾-inch wide Firthite tipped skiving tool forming a brass sink fixture from the rough casting in one pass at 320 revolutions per minute at 2½-inch feed removing about 1/32 inch of stock. This is interesting because it represents a case of carbide being applied to a very old Warner and Swasey turret lathe at no increase in speed over previous tools, yet this $181 carbide tool returned $2,623 in indirect sav-

* We are indebted to Mr. B. P. Graves, Director of Design, Brown & Sharpe Manufacturing Co., Pawtucket, R. I., for this valuable formula.



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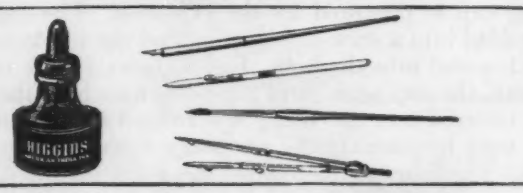

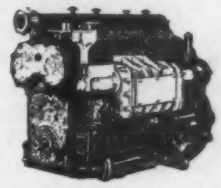

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ings in the first six months of its use through longer life between grinds and a finish on the work which made buffing before chrome plating unnecessary.

The last tooth of this huge hydraulic surface broach (Fig. 8), which broaches the top of the motor block shown in one pass, is Firthite. This setup produces a 2-inch radiator nipple complete every 35 seconds. Rough and finish turning at 250 feet per minute, 0.024 feed, gives about 10 seconds actual machining time. These cast iron Diesel tractor pistons (Fig. 12) are rough turned, faced and grooved in 60 seconds and finish turning and grooving are done in 36 seconds.

Fig. 14 shows a carbo lathe set-up to machine Diesel cylinder sleeves. This Porter Cable Carbo Lathe is shown with Firthite tools for turning 200 Brinell alloy cast iron cylinder sleeves at 223 revolutions per minute (about 250 feet per minute) at 0.010 feed, producing an average of 200 pieces per grind. A high run of 545 pieces per grind is on record, but the users prefer to change the tools for resharpening at the end of each day's run.

In turning, facing and boring bull gears (Fig. 13), Firthite produced 60 pieces in 8 hours, using a cutting speed of 160 surface feet per minute for roughing and 240 surface feet per minute for finishing at a cost of $0.135 per piece. On this operation high speed steel tools produced 29 pieces in 8 hours, using a cutting speed of 85 surface feet per minute at a cost of $0.263 per piece.

Sintered carbides were originally priced at $1.00 per gram or $453.59 per pound. This price has been repeatedly reduced over the past decade until now the material is available in units at 45 cents per gram and in large quantities at less than 20 cents per gram. This will provide an impetus to the future rapid expansion of use of sintered carbide tools.

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SEARCHING FOR OIL

(*Continued from page 9*)

at which a fine wire which serves to set off the detonating cap is ruptured by the explosion. The cap is embedded into a stick of dynamite and the whole assembly is lowered into the hole. Fig. 5 shows a stick of dynamite, the cap wires, and the poles by which the charge is lowered into the hole. A standard blasting machine is used to generate the necessary voltage to set off the cap which in turn detonates the dynamite.

A precision time scale is recorded simultaneously on the record. The timing is controlled by a tuning fork, which in turn drives a small synchronous motor on the shaft of which a disk shutter interrupts a beam of light making fine lines transversely across the record. The closest lines are 0.01 second apart, making it possible to estimate to a 0.001 second.

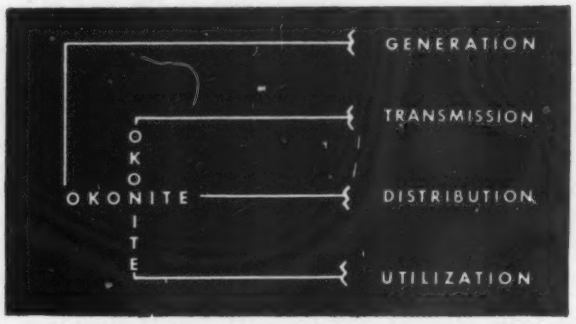
In some territories, notably in Kansas, Oklahoma, and West Texas, correlation shooting is most widely used. In these areas beds are generally flat or only slightly dipping, and are continuous over a wide area. The correlation seismic survey technique consists of tracing a given bed or beds by noting the time of arrival of the reflected wave (which is approximately the same from one shot point to another) and the "character" of the reflection (appearance of the reflected wave on the record). In other territories, notably on the Gulf Coast and in California, dip shooting is most widely used. The process consists of not only determining the depth of a given reflecting bed but also the angle it makes with the horizontal (angle of dip). The angle of dip sometimes reaches a value as high as 80 to 85°.

A record yields two observables. One is the arrival time of the reflection, which is the interval of time between the instant of explosion and the time of arrival of the *reflected* energy at the surface, and the other, the moveout time, which is the difference in the time of arrival of the reflection at the first and the last oscillograph trace. The moveout is due to the dip of the reflecting horizon and the finite distance on the surface which is occupied by the entire group of seismometers (commonly known as the seismometer spread). The moveout is likewise a function of the depth of the reflecting bed and the velocity of propagation. Fig. 4 shows a portion of a typical record, showing the arrival and the general appearance of reflections.

In order to compute the depth and the dip, the only quantity required in addition to the arrival time and moveout is the velocity of propagation of the seismic waves. The latter is determined for a given territory by "shooting a well," *i.e.*, lowering a special seismometer into a deep bore hole (generally an abandoned or a dry oil well), shooting a charge of dynamite close to the surface (at the bottom of the weathered layer), and recording the time of arrival of the energy at the seismometer. The velocity which is thus determined is the average velocity to a given depth. The average velocity for the weathered layer (unconsolidated layer directly below the surface) is about 2,000 ft./sec., increasing suddenly to 6,000 ft./sec. directly below it, and gradually increasing with increasing depth to values of 15,000 ft./sec. or more.

Since the process of computation of the angle of dip and the depth to any particular bed directly from the values of the time of arrival, the moveout time, the average velocity, and the length of the spread is rather complex, charts are prepared which contain all the parameters involved. Then, knowing the arrival time and the moveout time for any reflection, the correspond-

THE 4-ø ELECTRICAL SYSTEM



Okonite Wires and Cables are designed for every condition of use in each of these phases of any electrical system.

A 220,000-volt transmission cable or the smallest control wire may be the vital link in the chain, and seven laboratories in the Okonite factories provide the testing facilities that insure equivalent strength in each link.

There are many bulletins available on Okonite products that will help in solving problems involving insulated conductors.

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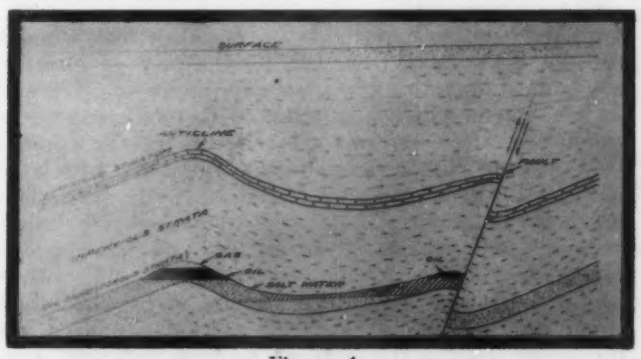

Figure 4

"The Raleigh Touch"

The swashbuckling Sir Walter Raleigh! Few men's lives have been packed with more adventure and achievement. Yet Sir W. will be remembered longest for his gallant service to a lady.

We took a leaf from Raleigh's notebook and made it our code of business. That was nearly twenty years ago. In that span we have made countless friends in the great fraternity of engineers. It is for our wide selection of parts, our performance guarantee, our bedrock prices that these engineers come to us. We think it is for our Service that they—and you—will remember us.

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ing angle of dip and depth to that bed are easily computed from the chart. A contour map of the area is then prepared, showing the structural appearance of the subsurface region. All depths are referred to the sea level.

In general the energy received by a seismometer can be separated into three parts: first, the ground roll — a surface wave which is of inherently low frequency (10–20 c.p.s.); second, the reflected energy (around 50 c.p.s.); and third, wind disturbance and general ground unrest (above 100 c.p.s.). By suitable frequency discrimination circuits the reflected energy alone is made to stand out.

At this time something may be said of the equipment and the personnel comprising a seismic surveying crew. The equipment, all of which is mounted on trucks, consists of a rotary drill for drilling the shot holes, which range from 20 to 500 feet in depth, a water truck which carries drill pipe and water for drilling, a shooting truck which carries dynamite and water to tamp the charge, and the recording truck, which carries instruments and cables.

The crew is composed of an office force and a field force. The office force consists of a party chief and two computers. The field force consists of an observer, an assistant observer, a shooter, a shooter's helper, the driller, the driller's helper, a surveyor, a rodman, and a few laborers. The duties of the party chief include the supervision of the entire crew and the interpretation of data. The computers assist the party chief in the analysis of the records, perform the necessary computations, and plot the geological data which the records provide. The observer, who is in direct charge of field operations, takes the actual records and sees to it that his instruments are in good working order. The assistant observer develops the records and generally aids the observer in the field. The shooting crew takes care of the shooting, and the drilling crew of the drilling. The surveyors tie in the elevations to the nearest bench marks and establish the locations of the shot holes and the seismometer spread. The party chief, the computers, the observer, the assistant observer, and surveyor are technically trained men.

Fig. 4 shows two of the more common geological structures which often bear oil and the manner in which oil is trapped. In addition, oil is found on the flanks of the intrusive salt plugs or domes of frequent occurrence on the Gulf Coast. It must be clearly understood, however, that the geophysicist does not directly determine the presence of oil, except possibly by the use of the soil gas analysis method. He merely surveys the subsurface strata and submits the map obtained to a petroleum geologist. The latter must determine, from the geological information available, the probability that the geophysically indicated structure will be productive of petroleum.

The field of prospecting is far from being saturated. While research positions are difficult to obtain, a position on the field force to a man with the right training and temperament can almost always be secured.

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Made of extra quality cotton yarn, carefully inspected, and guaranteed free from all imperfections of braid or finish.
The colored spots are our trade-mark, used only with this quality.
We make braided cord of all sizes, kinds, and colors for all purposes, including sash cord, clothes lines, trolley cord, signal cord, arc lamp cord, and many special cords for special purposes; also cotton twines.

CATALOGUE AND SAMPLES GLADLY SENT ON REQUEST

SAMSON CORDAGE WORKS **89 Broad Street, Boston 9, Mass.**

VOLCANOES, MUSSOLINI, DISEASE

(*Continued from page 11*)

law. At each minimum and shortly after, all the spots are found in the vicinity of solar latitude 30 degrees on both sides of the equator. As the cycle grows older, the average position of the spots unmistakably moves toward the equator, until at the next minimum the cycle dies in the vicinity of latitude 10 degrees, while a new one arises at the higher latitude. That such determinate and regular features should be present in the process of sunspots seems in direct contradiction with the consistent failure to break down the curve into simple components, and it is for this reason that Halm, at the beginning of the century, suggested the outburst hypothesis.

Halm suggested that perhaps, if one approached the analysis from the viewpoint of the individual cycles, a curve might be found to represent all the cycles, provided two or more parameters in the equation were kept variable to represent the unique characteristics of each cycle. Only a few years ago Waldmeier worked on this hypothesis. He found that a certain curve, containing two adjustable parameters, fitted most of the cycles fairly well. He gave the curve in its graphical form, but did not analyse it mathematically. But now Stewart and Panofsky, of Princeton, seem to have found the right direction of attack. The results of their analysis may be found in a recent paper in the *Astrophysical Journal*. It is an equation containing four disposable parameters. It fits well the curve of yearly averages of sunspot numbers, and, with a correction here and there, ought to fit the data of monthly averages very accurately.

The outburst hypothesis presupposes that when a sunspot cycle is on the wane, some sort of stresses, mechanical or otherwise, become increasingly great. At a moment which a number of factors cause to be propitious, these stresses are relieved by the appearance of spots, changes in radiation, and a host of related variations. From then on the number of spots, their position, and their polarity are all governed by some explicit law which can be represented as a first approximation by the Stewart-Panofsky equation. The values of the adjustable parameters are fixed by the initial conditions, and as soon as these can be evaluated, the remaining trend of the cycle can be predicted very accurately. As is right, the hypothesis does not limit itself to sunspots, but infers that the process of the outburst is fundamental, and governs also the variations in radiation, in the magnetic field, in the corona, the faculae, the prominences, and perhaps in some sort of corpuscular emission. It may be that at a later date the relationship between the parameters of successive cycles may be fathomed, but it is probable that the same factors will contravene any such success as those which are fast discouraging the Fourier analysts and the periodometrists. Such a study, while not promising to predict long-term trends in the variation of solar activity, augurs the day when, with the help of statistics concerning the rise from minimum to maximum in a cycle, the drop from maximum to minimum will be accurately predictable. That we should have to remain content with such short-term prediction does not mean that the entire value of solar-terrestrial correlation work is worthless from the point of view of prognosticating earthly phenomena. For instance, weather forecasting, even long-range forecasting, does not concern itself with weather trends more than a few years in advance. Radio disturbances, compass deflections, the effect of the solar-activity factor on plants, animals, and man—none of these need be predicted very long in advance.

The attainment of a facility in the prediction of solar changes cannot but be a big help to all those "apes bereft of their tails and grown rusty at climbing" who hope at length to be able to sound out their miserable future. Such an attainment appears to be definitely in the offing.

WHY DO COMPANIES ADVERTISE IN COLLEGE TECHNICAL MAGAZINES?

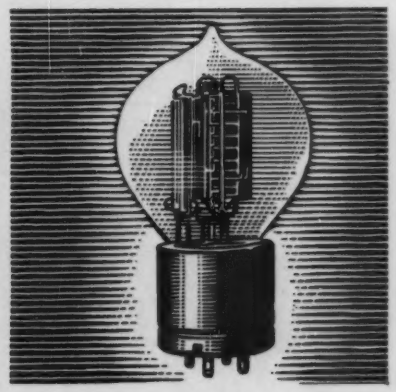
What benefits are derived from soliciting engineering students who as yet have nothing to do with business? The answer is that they are soliciting good will which will pay dividends in the future. You and I are the ones that in the years to come will be dealing with these companies. We are the purchasing agents who will be buying their goods, or we may be selling goods to them; in any event it is then that their present investment in advertising with the college magazines will pay dividends. For through their continued advertising we have a knowledge of their functions, of their personnel, and of the services they perform to the people of the world. All of this background of these companies will not be forgotten by the students who are the important men of tomorrow.

RIGHT OR WRONG?

A 2-minute test for telephone users

1. The Bell System handles about 48,000 telephone calls per minute, on the average.

RIGHT ☐ WRONG ☐



2. One of the first uses of vacuum tubes was in telephony—years before commercial radio telephony.

RIGHT ☐ WRONG ☐

3. The largest telephone cable used by the Bell System contains 2424 wires.

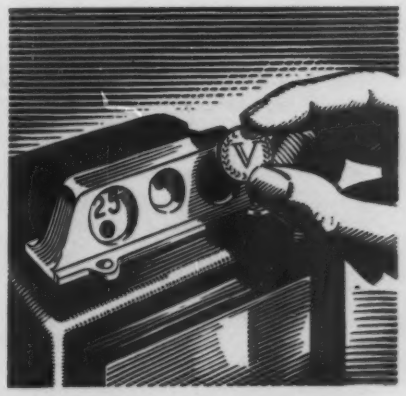
RIGHT ☐ WRONG ☐

4. The Bell System employs about as many people as live in the city of Dayton, Ohio.

RIGHT ☐ WRONG ☐

5. This is part of a page taken from a telephone directory published in the United States.

RIGHT ☐ WRONG ☐



6. Lowest rates to most out-of-town points are available every night after 7 P.M. and all day Sunday.

RIGHT ☐ WRONG ☐

ANSWERS

1. *Right.* In 1938 the average number of calls per day was about 70 million.

2. *Right.* The repeater tube, which makes possible long distance telephony, was first used in 1913.

3. *Wrong.* 3636 wires are packed into a cable about the size of a man's wrist.

4. *Wrong.* The population of Dayton is about 200,000 — while there are nearly 300,000 telephone employees.

5. *Right.* It is from San Francisco's Chinatown telephone directory.

6. *Right.* Why not telephone family and distant friends oftener?

AMERICAN TELEPHONE & TELEGRAPH CO. AND ASSOCIATED COMPANIES — BELL SYSTEM

BELL TELEPHONE SYSTEM

G-E Campus News

NEW-TYPE STREAMLINER

A NEW-TYPE 125-mile-an-hour streamliner — the 5000 horsepower steam-electric train now being put through its final tests by G-E engineers—soon will be speeding on its first westward run over the Union Pacific's historic "Overland Route."

Nearly two years have been spent by General Electric and Union Pacific engineers in designing and building the streamliner. The result is that the power plant of the new train is capable of doing twice the work of a conventional steam locomotive for each pound of fuel used, and of making three times the mileage without stopping for fuel or water. Six large motors in each of the two cabs drive the locomotive, the electricity being supplied by a geared turbine-electric generating unit similar to those used on many ships.

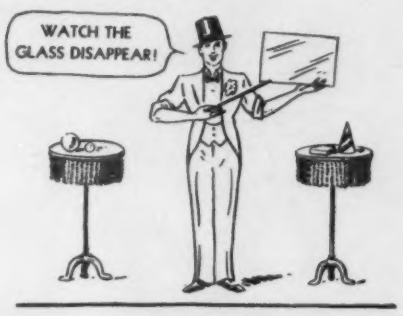
As the new 15-car streamliner speeds between Chicago and the Pacific Coast, at times winding through passes more than 7000 feet above sea level, it will be another symbol of the constant search by General Electric's transportation engineers for more efficient means of travel. This search is one in which the engineer with years of experience gives invaluable training to the Test men - young student engineers recently graduated from college —who assist him.

TELEVISION AT THE NEW YORK WORLD'S FAIR

IF YOU have a favorite line or two from Kipling or a famous Shakespearean speech you like to give now and then, consider the *ne plus ultra* of settings for the presentation—a complete television studio, with an audience as standard equipment, recently announced by Dr. W. R. G. Baker, Union '16, managing engineer of the General Electric radio division and an ex-Test man.

For you are invited to turn actor in the G-E building at "The World of Tomorrow," the New York World's Fair. At your service will be a program director, who will initiate you into the experience of acting before the camera, and complete television equipment of the latest design—receivers, camera, transmitter. And between acts you will be able to see and listen to programs that are being broadcast by television stations throughout the New York area.

Demonstrating television to the public is not new to General Electric engineers. Nine years ago, Dr. E. F. W. Alexanderson—one of the G-E consulting engineers and an ex-Test man—and his assistants demonstrated television to a theater audience in Schenectady. But great advances have been made since then, and when you act for your friends at New York you will be using the latest equipment that science has to offer.



NOW YOU SEE IT— NOW YOU DON'T

IN THE G-E Research Laboratory, at Schenectady, there is a framed photograph which at first glance does not appear to be unusual in any way. But when it is viewed from an angle at which the glare of light reflected from the glass becomes noticeable, the picture does tricks —part of it becomes almost obscured by the glare, yet the rest remains clearly visible.

The explanation is that each surface of the clear portions of the glass is coated with a transparent film—a film four millionths of an inch thick, or one-quarter wave length of light, and having the proper refractive index. These films, recently developed by G-E scientists, cause the light rays reflected from the film surfaces to counteract one another. The reflection of light from the glass is thereby prevented. Whereas the process is still in the laboratory stage, it is believed that it will soon be available for many optical uses.

GENERAL ELECTRIC

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